Board of Equalization Building

450 N Street, Sacramento, CA 95814

Corroded Drain Line Investigation

Prepared for DGS

Interactive Resources Project No. 2011-099-01

IDGS Contract No. 3158936 (BPM #028)

November 25, 2013

Contents

Executive Summary

The scope of this investigation was originally to provide a detailed evaluation of failed waste pipes serving small sinks in break rooms, located on each floor of the Board of Equalization building in Sacramento, CA. The scope expanded to include waste and vent pipes serving janitor sinks, and to soil and vent stacks serving water closets and other fixtures.

The building at 450 N Street, Sacramento CA is a high rise office structure, approximately 23 years old, built under a design/build contract, and the primary tenant in the building is the State Board of Equalization, (BOE). The sanitary drainage system serves the toilet rooms, janitor's rooms and 55 break room sinks.

The damage to the interior of waste piping at the above site is corrosion, due to the congestion of waste materials in the pipes and due to a poor plumbing installation. It also finds that the corrosion damage has spread throughout the system, affecting most of the drains from break room sinks, most of the drains from janitor sinks and some of the drains in the core toilet areas. Although the damage found is widespread, the severity of the damage is highly variable and greater in the drain pipes than in the vent pipes.

Waste materials enter the drains from break room sinks and janitor sinks, and they persist there because there is not adequate flow to carry the waste away. Water flows slowly because the pipe slope is too flat and because air cannot readily flow into and out of the pipes to replace it. The faucets on break room sinks were found to have flow-restrictors and temperature mixing valves. These devices conserve water, conserve energy, and prevent scalding; however, they contribute to congestion in the pipes because there is less water for flushing, and the cool soaps and fats congeal in the pipes.

Serious code violations were found in the plumbing installation, including inadequate slope and restricted venting, and many of the break room sink fixtures are not suitable for their current use. Many existing bar sinks are being used as kitchen sinks to prepare food. Food prep sinks require strainers, higher water flows and higher water temperatures than bar sinks or hand wash sinks.

Laboratory analysis from this study concurs with a previous investigation of more limited scope that pipe damage is a result of graphitic corrosion. Videos taken in this study show, and laboratory analysis has confirmed, that corrosion damage has cascaded and spread throughout the drain and vent system.

A brief summary of recommendations from this investigation includes:

1. Break Room Sinks: Most importantly, keep food waste out of the sinks, clean pipes, maintain the system, update record drawings, and replace drain pipes. Second, replace selected break room sinks with kitchen sinks.

2. Janitor Sinks: Clean pipes, maintain the system, update record drawings, and replace drains serving these sinks.
3. Soil and Vent Stacks: Most importantly, clean pipes, maintain soil and vent stacks, and update record drawings. Second, confirm riser clamps are secure at each floor, replace poorly sloped drains at the base of the soil stacks, replace undersized yoke vents and install new yoke vents and determine where stacks have been compromised by corrosion and either line or replace those sections. Third, install screened caps on vents.
4. Future Standards: Develop and implement a building standards document, specifically for the proper maintenance, installation and design of existing plumbing piping and any future plumbing piping in the building. Require review of this by any plumbing contractors working in the building.

Introduction

This investigation was conducted to address a history of break room sink drainage problems and expanded to include some janitor sink drainage and soil and vent stack drainage. This report is not intended to address toilet room drainage, so the exclusion of toilet room drainage in this discussion does not imply any conclusions about the condition of toilet room drainage. The following terminology and background information is given as a foundation to findings, discussion and conclusions.

Terminology

1. **Building Sanitary Drain.** The lowest horizontal piping of a building drainage system that conveys sewage discharged from fixtures in the building to a public sewer.
2. **Building Trap.** A liquid seal device in a building sanitary drain that prevents the back-passage of air between a public sewer and the building sanitary drainage system.
3. **Corrosion.** The loss and eventual failure of metals and alloys from the electrochemical reaction between water and the pipe material. General corrosion is the uniform breakdown of pipe material over its entire exposed surface. Localized corrosion affects only a small area of the pipe surface.
4. **Drain.** A pipe that carries waste or waterborne wastes in a building drainage system.
5. **Intergranular Corrosion.** A particular type of corrosion that occurs in the pipe wall when materials in the grain boundary of some alloys are less resistant to the corroding agent than the grains themselves, destroying the bonds between the grains.
6. **Plumbing Vent.** A pipe provided to ventilate a plumbing system, to prevent a trap siphon and backpressure, or to equalize the pressure within the drainage system.
7. **Sanitary.** In plumbing this denotes any drainage system that conveys human waste.
8. **Sewage.** Liquid waste containing animal or vegetable matter in suspension or solution and that may include chemicals in solution.

9. **Soil Pipe.** A pipe that conveys the discharge of water closets, urinals, clinic sinks, or fixtures having similar functions of collection and removal of domestic sewage, with or without the discharge from other fixtures, to the building drain.
10. **Stack.** The vertical main of a system of soil, waste, or vent piping extending through one or more stories.
11. **Trap.** A fitting or device designed and constructed to provide, when properly vented, a liquid seal that will prevent the back passage of air without significantly affecting the flow of sewage or wastewater through it.
12. **Waste Pipe.** A pipe that conveys only liquid waste, free of fecal matter.
13. **Yoke Vent.** A pipe connecting upward from a soil or waste stack to a vent stack for the purpose of preventing pressure changes in the stacks.

Background Information

The building at 450 N Street, Sacramento CA has 24 floors, approximately 25,000 square feet per floor, and is located downtown near the Sacramento Capitol Mall. It was built in 1990-1992 under one of the State's early design/build contracts, and the primary tenant in the building is the State Board of Equalization, (BOE). The sanitary drainage system in the building is constructed of gray cast iron pipe and serves the toilet rooms, janitor's rooms and 55 hand sinks in the tenant area surrounding the core. According to DGS staff, the design/build process on this project did not receive an adequate level of construction inspection during construction.

Assignment and Scope of Services

Under DGS Contract No. 3158936, Amendment 7, dated February 27, 2013, Interactive Resources was initially tasked to:

> Provide labor, equipment and materials required to conduct a thorough forensic investigation into the cause and extent of pipe corrosion in cast iron drain pipes serving multiple break rooms on each of the 23 floors at the Board of Equalization Building (028) located at 450 N Street, Sacramento, CA 95814.

Specifically, the Scope of Services included the following:

1. Review the record drawings of existing shell conditions and existing tenant improvement conditions.
2. Review previous data and analyses reports by the State.
3. Conduct a field survey of the site, evaluate the environmental conditions surrounding the pipes and identify procedures where pipe samples will be taken.
4. Attend (3) meetings on-site at start of investigations.

On March 5, 2013, GHD entered into a sub-consulting agreement with Interactive Resources for Mechanical Engineering and Environmental Engineering Services, as initially described in the

Abbreviated Form of Agreement between Architect and Consultant for Consulting Services, dated February 11, 2013. The scope of work outlined there is briefly summarized here:

1. Investigate the cause and extent of pipe corrosion in cast iron drainage pipes at the above address.
2. Review the record plumbing drawings.
3. Review previous data and analysis.
4. Develop an investigation plan and schedule, including a contingency plan for breaching rated wall assemblies in an emergency.
5. Develop a scope of work for hygienically safe access in a compromised environment.
6. Conduct the field work, taking videos and samples of pipe, liquid and air.
7. Employ the services of a hazardous materials contractor to gain safe access to the building assemblies where necessary for observation and sampling. Monitor containment operations in each area to verify work is complete and area is clean.
8. Employ the services of a plumbing contractor to video camera pipes, extract pipe samples and replace any piping removed, leaving the facility clean and fully functional each day.
9. Employ the services of a testing laboratory to measure pipe wall thickness on site and to analyze pipe and liquid samples in the laboratory, and another laboratory to analyze mold spore trap samples for safe access.
10. Present findings and recommendations in a written report.

By late April 2013, the scope of work had increased to include weekly meetings, weekly work plans, and weekly reporting, a shift to weekend-only work and a second plumbing contractor was employed for the pipe fitting work. In addition, an emergency plan of action was developed with the state fire marshal to maintain safe occupancy status in the building in the event that rated wall assemblies had to be breached to repair an unforeseen major leak.

The expanded scope was described in Amendments 8 through 11 and 13, the last dated August 12, 2013.

Project Team and DGS Project Manager

The DGS project director is:

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Interactive Resources assembled a team for the project that utilized GHD as the prime sub-consultant.

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GHD, in turn, retained a team of consultants and contractors, listed below:

1. **Testing Engineers, Inc.**
    a. 2811 Teagarden Street, San Leandro, CA 94577
    b. (510) 835-3142
    c. harbabi@testing-engineers.com
    d. TEI measured pipe wall thickness on site, and provided in-depth pipe and water sample analysis in their laboratory.
2. **Brice Mechanical, Inc.**
    a. 3734 Bradview Drive, Sacramento, CA 95827
    b. (916) 368-0220
    c. rick@bricemechanical.com
    d. BMI removed, relocated, and/or replaced pipe, fittings and fixtures as needed for video camera access and for the extraction of laboratory samples.
3. **Flowrite Plumbing, Inc.**

a. 9219 East Laguna Way, Sacramento, CA 95758
b. (916) 496-0935
c. jimmy@flowriteplumbing.net
d. FPI provided all video camera imaging inside the piping for this investigation.

4. **Allied Environmental Inc.**
   a. PO Box 2240, Shingle Springs, CA 95682
   b. (530) 676-0595
   c. Alan.salmen@comcast.net
   d. AEI provided hazardous materials containment and clean-up services for this investigation.

This field investigation included 11 site surveys over a 14-week period, from April 8 to July 13, 2013. Surveys occurred off-hours, and each survey involved a separately vetted work plan, a pre-meeting, crew management, and a post-meeting to report findings. After the field investigation, lab analysis occurred on pipe samples taken in the field.

Site surveys occurred on the following 11 levels: Roof, 24th floor, 22nd floor, 21st floor, 19th floor, 17th floor, 14th floor, 10th floor, 5th floor, 4th floor and 3rd floor.

Observations

Plumbing in each break room consists of one bar sink, 15inch by 15-inch and 6-inch deep, no strainer, with a single mixed temperature (110F), sensor activated, low flow (0.5 gpm) gooseneck faucet. This fixture is appropriate for hand washing and the simplest of beverage preparation.

Occupants were observed using break rooms as kitchens to prepare food on several occasions. One or two refrigerators, one or two microwave ovens, and one or two automatic coffee makers are common in the break rooms. None of the break room sinks was found to have accessories to manage food or beverage waste or keep it out of the sanitary drainage system. There were no basket strainers, garbage disposals, automatic dishwashers or compost buckets found in any of these rooms.

Liquid levels in flush fixtures in the core area were repeatedly observed fluctuating up and down during occupied hours, and levels were also noticed fluctuating to a lesser degree off-hours and on weekends. This is typically caused by pressure fluctuations in the piping system, related to restrictions in the vent piping.

Because of concerns about potential encounters with mold, the BOE retained industrial hygienist, Larry Sandhu of Hygiene Technology International was present during all field work, as were Chris Smith and/or Erica Sattar of GHD. The only suspected encounter with mold occurred behind a toilet in the men's toilet room on the 24th floor. The opening was sealed and air samples taken by GHD and analyzed by a laboratory. No elevated level of mold spores was detected.

Previous Analysis, Martin Testing Laboratories Report, dated July 13, 2012.

The Martin Testing Laboratories (MTL) report is limited in scope to two pipe samples from the 4th floor. MTL found relatively large concentrations of phosphorus and sulfur in their samples, and concluded that the problem is graphitic corrosion, where graphite is cathodic to the iron in the matrix, selectively leaching out the iron, leaving a porous graphite network and iron oxide deposits.

MTL's recommendations for prevention include:

1. Replacing cast iron pipe with white cast iron pipe.
2. Controlling the environment with water traps and alkaline drain cleaners.
   Providing cathodic protection with either impressed current or sacrificial anodes.

We concur with their findings on intergranular corrosion, and MTL's conclusions are consistent with the findings of this investigation, but we have the following comments on their recommendations:

1. White cast iron, (where carbon is present as silvery iron carbide vs. the gray graphite flakes found in gray cast iron), is more resistant to wear and abrasion. If it can be found, it is very expensive, hard, brittle, and difficult to work with.
2. Properly vented liquid traps are necessary throughout a sanitary drainage system to keep sewage gases out of the occupied space. However, a building trap is neither required nor allowed in the City of Sacramento, (see discussion on a building trap in Options below). We do recommend a multi-faceted drain treatment program over an alkaline drain cleaner. (See discussion about on-going system maintenance in Options below).
3. Cathodic protection would help control galvanic action on the cast iron, but it would be prohibitively expensive since thousands of pipe sections and fittings in the building are isolated by rubber gaskets and would each require bonded ground couplings for cathodic protection.

Findings

Record Drawings

Existing record drawings of the sanitary drain, waste and vent (DWV) piping in the building were found in most cases to over-simplify the installation, in many cases to be significantly inaccurate, and to include plumbing code violations in the sizing of vent piping.

The as-built routing of drain and vent pipes serving break room sinks in the tenant areas was found to have significant deviations from the record drawings. The Tenant Drawings, by JW McClenahan ca. 1992, have individual floor plans for floors 2-24 showing drain and vent piping for the 55 break room sinks in the building. These sink drains are typically shown routed to "Stub for T.I." connections on the floor below, and the vents routed to "Stub for T.I. connections" on the same floor. However significant variations in drain and vent pipe routing were found. For example, sink drains and vents were found to combine locally and penetrate floors vertically, hidden in partition walls, into more convoluted pipe runs before connecting to fewer of the "Stub for T.I." connections. We found many "Stub for T.I." drain and vent connections still capped and available throughout the building.

The record drawings that show piping serving janitor's sinks and soil and vent stacks for core construction, by Capital Engineering Consultants ca. 1990, include waste (drain) and vent riser diagrams and one typical core plumbing plan representing the exact same plumbing layout on all twenty floors. Nearly every floor was found to have unique variations to this layout, (routing, offsets, combining fixtures, fittings), that are not documented. The plan shows drain and vent stubs above the ceiling for "future" tenant improvements, at four locations on each floor, which were not all confirmed. Hand notations on the core drawings refer to Information Request # 223 for a "new plumbing diagram", which could not be found.

The riser diagrams on the record drawings for the core area show 4-inch yolk vents between pairs of 6-inch drain and vent stacks, located on the 20th, 15th, 9thand 4th floors. 4-inch yolk vents were found on the 20th, 9th and 4th floors, but no yolk vents could be found on the 15th floor.

Video Scans

A camera was inserted into drain and vent piping in 27 locations in the building, and video scans were recorded of various lengths of pipe depending primarily upon amount of debris and number of fittings in that run. The video scans provide good qualitative information on the interior condition of pipe such as pipe roughness, pipe slope and the nature of obstructions to fluid flow and air flow in the pipes. Overall, the video scans confirm that there are many more bends, fittings and offsets than are shown on the record drawings, drains are congested, and that pipe corrosion damage is highly variable.

Most of the drains serving break room sinks that were surveyed had rough pipe surfaces. Many had inadequate slope and standing water. Many were very congested with soft food debris, and many were nearly completely plugged with debris. There were several cases where scanning was aborted due to severe congestion in the drain line and fear of contributing to plug a pipe. Most of the vents in the tenant areas were in better condition than the drains, pipe wall roughness was highly variable, and some vents were significantly congested but none approached completely plugged.

The nature of obstructions in the break room sink drain pipes appeared to be mostly soft food deposits and standing water, which are easily moved by the camera and often block the camera lens. Harder deposits were seen in many places where not obscured by the softer deposits. The harder deposits impeded camera movement and appear as rounded projections on the pipe wall, or tubercles. In the laboratory these deposits were found to conceal pitting in the cast iron and to contain iron-oxide, sulfur and carbon, all known to be either symptoms of or contributors to the corrosion of gray cast iron.

The video scans of the break room sink pipes show a variety of pests normally found in soil pipe. The pests reside in the vent piping and to drop into the drain pipes for their sustenance, which are severely congested with food waste and which flow only occasionally. The appearance of food waste and pests in the system indicates microbial activity as well, although this was not quantified in this investigation. Microbial activity is known to contribute to the corrosion of iron pipe.

In scans of the two main vent stacks, corrosion damage appears to be localized but generally not severe enough to warrant replacement. The two 6-inch vent stacks appear to be generally serviceable, but some severe corrosion damage was found at the 2nd and 3rd floors. The number of fittings observed was consistent with the number of vent branches shown in the core drawing riser diagrams within one or two branches.

The two 6-inch drain stacks appear to be generally serviceable, but corrosion damage is variable, localized and more severe at the 19th and 11th floors. Pipe slope was found to be very poor at the base of the drain stacks beneath the 1st floor, as evidenced by standing water there.

Wall Thickness Measurements

Pipe wall thickness was measured for several reasons. During the site investigation, wall thickness was measured to determine the best location to insert a camera into the piping, without risk of damaging a weakened pipe and causing a spill. Later, wall thickness data helped determine correlations between pipe corrosion and several factors including pipe slope, qualitative visual images in the pipes, and the accumulation of debris in the pipes.

Testing Engineers Inc. was employed to measure pipe wall thickness on site and to analyze pipe and fluid samples taken back to their laboratory.

Pipe wall thickness measurements were taken at 37 locations on site and on 11 of 23 pipe samples returned to the laboratory. Overall, the corrosion damage found in the drain pipes was widespread, variable, and in many cases, severe. Corrosion damage observed in the vent piping was highly variable, from none to moderate, and severe in only one case. The following two comparisons were made of pipe wall thickness data.

First, pipe wall thickness was compared to the minimum allowed for manufacturers of new pipe, (ASTM standard A888). Pipe wall was found to be thinner than new pipe in 12 out of the 37 locations on site and in 7 out of the 11 pipe samples returned to the laboratory. Nominal and minimum ASTM pipe wall thickness for several pipe diameters are shown below:

Size, in	Nominal thickness, in	Minimum thickness, in
2	0.16	0.13
4	0.19	0.15
6	0.19	0.15

Break Room Sink Pipes: Approximately one third of all break room sink drains were thickness scanned, and about one fourth of these were found to have significantly thinned pipe walls.

Janitor Sink Pipes: These were concealed and not easily accessible, and thus none of these drains were thickness scanned.

Soil and Vent Stacks: About four feet of these were accessible above each restroom ceilings, but generally the stacks were not accessible from floor to ceiling on each floor. Stacks were thickness scanned above the 24th and 3rd floors only.

In the following 12 areas pipe wall was found to be thinner than ASTM standard minimum: 22nd floor at columns K-18, L-19, M-18 and M-21; 21st floor at columns L-19 and M-22; 17th floor at columns L-19 and M-22; 5th floor at M-22; 4th floor at column L-18; and 3rd floor at columns L-19 and M-19. See attached plans of these areas.

Secondly, the difference between the thickest wall measurement and thinnest wall measurement in the same sample was compared. Pipe walls at 50% or less than the thickest measurement in that sample were found in two out of 37 site measurements, and in four out of 11 laboratory measurements. Pipe walls at 50% or less occurred in the following five areas: 22nd floor at column K-18; 17th floor at column M-22; 5th floor at M-22; and 3rd floor at columns L-19 and M-19.

Additional Information in Appendices

A summary of the findings and observations from this investigation are presented in Appendix A, BOE Investigation Findings and Appendix B Floor Plans, showing where the data and samples were taken in this investigation. Video images are included in Appendix C, External Drive with Video Images.

1. The amount of deposits found in the pipes was observed and ranked from 0-3, none to severe.
2. The visible signs of corrosion were observed and ranked from 0-3, none to severe.
3. The loss of wall thickness was measured and ranked from 0-3, none to severe. Pipe wall thickness measurements were compared in two ways. First, against the nominal and minimum barrel thickness for each pipe size according to *ASTM A888-09 - Standard Specification for Hubless Cast Iron Soil Pipe and Fittings for Sanitary and Storm Drain, Waste and Vent Piping Applications*. Second, the thinnest measurement taken is compared to the thickest measurement taken in the same section of pipe or fitting.
4. Pipe slope was measured and ranked from 0-3, excellent to poor.
5. Pipe support was observed and ranked from 0-3, excellent to poor.
6. Pipe routing deviation from record drawings was observed and ranked from 0-3, none to severe.

7. pH was measured and listed from more acidic to less acidic, 4.5-6.

Discussion and Conclusions

Present Conditions

This study did not survey every pipe run in building, and can only report on pipe runs investigated.

Break Room Sink Pipes:

1. Drain pipes from break room sinks were found to be heavily congested with food waste. This spawned microbial growth, attracted pests, and plugged the pipes, causing over flow in some areas.
2. About one-half of the drain pipes serving break room sinks were found to have sections with inadequate slope, insufficient support, standing water and solid deposits. The CPC requires a minimum slope of 2% or ¼-inch per foot for a 2-inch drain pipe, which will develop a velocity of about 2 fps. Velocities less than 2 fps will not flush and scour the pipes properly.
3. The break room sink fixtures observed are inappropriate for food preparation service. Sinks have no strainers, faucets deliver low flows and temperatures are too low. Water conserving, occupant sensor-activated type faucets deliver warm (110F) water at 0.5 gpm. This is appropriate for hand washing but does not flush food waste out of the system. Velocities are too low and the warm water they deliver is not hot enough to keep fats and oils in suspension. Thus solids deposit and fats congeal and accumulate in the drain pipes before they reach stacks and mains with greater flows.
4. The drainage pipes from break room sinks showed widespread corrosion damage, to the point of leaking in some areas, and the symptoms are consistent with graphitic corrosion of gray cast iron. Substandard pipe wall thickness and video images were found in approximately one quarter of the break room sink drains surveyed.
5. Chemical analysis of the debris in break room sink drain pipes found a low Langelier Saturation Index[1], with acidic conditions and sulfur compounds present. These are common when food

[1] Langelier Saturation Index (LSI) The Langelier Saturation Index (sometimes Langelier Stability Index) is a calculated number used to predict the calcium carbonate stability of water. It indicates whether the water will precipitate, dissolve, or be in equilibrium with calcium carbonate. In 1936, Wilfred Langelier developed a method for predicting the pH at which water is saturated in calcium carbonate (called pHs). The LSI is expressed as the difference between the actual system pH and the saturation pH:

LSI = pH (measured) — pHs

- For LSI > 0, water is super saturated and tends to precipitate a scale layer of $CaCO_3$.
- For LSI = 0, water is saturated (in equilibrium) with $CaCO_3$. A scale layer of $CaCO_3$ is neither precipitated nor dissolved.

waste breaks down and the chemical and microbial activity produces hydrogen sulfide gas and carbon dioxide gas, which condense to form sulfuric acid and carbonic acid. These acids are known to contribute to graphitic corrosion of cast iron.

6. Vent pipes from break room sinks exhibited variable accumulation of debris, often obstructing a third of the cross-sectional area of the pipe, but other vents were often clean. Substandard pipe wall conditions were not found in any of the break room sink vents surveyed.

Janitor Sink Drains:

1. Drain pipes from two out of twenty four janitor sinks in the building were video surveyed and found to be heavily congested with food waste, spawning microbial growth, attracting pests, and plugging the pipe. These drains were not accessible for pipe wall thickness measurements without cutting into walls or ceilings.
2. Both of the drain pipes serving janitor sinks were found to have sections with inadequate slope, insufficient support, standing water and solid deposits.
3. During this investigation it was learned that the janitor sink drains were reported to have a history of problems, including clogged drains and corrosion damage, and that all of the traps serving the twenty four janitor sinks had been replaced in recent years.
4. The drainage pipes from janitor sinks are highly suspected of having corrosion damage. The symptoms from video images and the history of problems are consistent with graphitic corrosion of gray cast iron. No pipe wall thickness measurements were taken.
5. Chemical analysis of the debris in janitor sink drain pipes found a low Langelier Saturation Index, with acidic conditions and sulfur compounds present.
6. Vent pipes from janitor sinks were not accessible without cutting into walls and ceilings, so they were not surveyed in this investigation.

- For LSI < 0, water is under saturated and tends to dissolve solid $CaCO_3$.

If the actual pH of the water is below the calculated saturation pH, the LSI is negative and the water has a very limited scaling potential. If the actual pH exceeds pHs, the LSI is positive, and being supersaturated with $CaCO_3$, the water has a tendency to form scale. At increasing positive index values, the scaling potential increases.

In practice, water with an LSI between -0.5 and +0.5 will not display enhanced mineral dissolving or scale forming properties. Water with an LSI below -0.5 tends to exhibit noticeably increased dissolving abilities while water with an LSI above +0.5 tends to exhibit noticeably increased scale forming properties.

It is also worth noting that the LSI is temperature sensitive. The LSI becomes more positive as the water temperature increases. This has particular implications in situations where well water is used. The temperature of the water when it first exits the well is often significantly lower than the temperature inside the building served by the well or at the laboratory where the LSI measurement is made. This increase in temperature can cause scaling, especially in cases such as hot water heaters. Conversely, systems that reduce water temperature will have less scaling.

Soil and Vent Stacks:

1. Video images were taken in this investigation of two soil stacks and two vent stacks, from the roof to the first floor. All four stacks were opened for video scanning above the 24th floor and 14th floor restroom ceilings. Video images show pipe routing varies from record drawings, poor slope at the base of drain stacks, and they show that although all stacks exhibit signs of corrosion, they are generally in good to fair condition.
2. The soil and vent stacks showed minimum to moderate corrosion damage, and the symptoms appear to be consistent with graphitic corrosion of gray cast iron.
3. Access to stacks for pipe wall thickness measurements was limited to sections above restroom ceilings to the deck above. Stack wall thickness was measured above the 3rd floor women's restroom only, where video images showed the worst signs of corrosion. Pipe wall thickness in soil and vent stacks was found to be substandard above the 3rd floor women's restroom.
4. All of the as-built yolk vents between drainage and vent stacks in the core area were found to be undersized, (4-inch), and some of the yolk vents could not be found where shown on the record drawings. According to the UPC circa 1990, yoke vents are required at each fifth floor, counting down from the uppermost fixture drain, and sizes are to be not less in diameter than either the drainage or the vent stack, (6-inches in this case). Hand notations on the core drawings defer to Information Request # 416 for "alternate yolk vent piping", but this IR could not be found. Poor venting restricts the ebb and flow of air, creating pressure fluctuations that obstruct the free flow of sewage in the system.
5. Video images show pipes that are back-sloped at the base of the drain stacks beneath the 1st floor, as evidenced by standing water there. This also contributes to pressure fluctuations and flow restrictions in the system.

Options

Break Room Sinks:

Food Waste

1. Cease putting food waste into existing break room sink fixtures.
2. At all break room sinks that are to remain, remove food storage and food preparation equipment, (refrigerators and microwave ovens).

Clean Pipes

Clean drain and vent pipes from break room sinks:

1. Clean pipes will slow down the rate of corrosion, improve flow and scouring, and reduce emergency calls for plugged drains and overflows. Cleanouts are not required by code in vent

pipes or in drain pipes above the first floor, although many cleanouts were found in drain pipes. On all floors, access for cleaning exists but will typically require removing some fittings. Pipe cleaning can occur after hours in a fully occupied building with little or no disruption to tenants (see discussion of pipe cleaning methodology below).

2. Pipe cleaning methodology. Pipe cleaning methods should be appropriate for the condition and access to the pipe, and should only be done by trained, experienced professionals.
   a. Drain Snake: A drain snake is a common method of opening a clogged drain pipe using a flexible cable or metal snake, with or without one of various head attachments, (spring coil, steel blade, or set of blades). The head and/or cable is inserted into the pipe and rotated by a hand crank or an electric motor for a limited distance and/or a limited number of bends in the pipe before friction becomes too great. If the waste plug can be broken up and pushed out to a larger pipe or vertical pipe, a drain snake will usually clear a clogged drain. In a long run of small pipe, there is risk that a drain snake can push the waste into a plug in the pipe. If the pipe material is already compromised, the snake head is sharp, and/or if the rotating force is great, a drain snake can break through a fitting or weakened section of pipe wall. The latter has occurred in this building, but during our investigation, BPM carefully snaked and cleared several plugged sink drain pipes without pipe failure.
   b. Flushing: Hydro-flushing is a common method of cleaning an open pipe that has been snaked and unclogged with a low pressure stream of water from a simple open hose, (no nozzle), operating under low pressure, (30 psi). Flushing rinses but does not scour the pipe, and there is a risk of water flowing back out of the point of entry (see maintenance below).
   c. Jetting: Hydro-jetting is used in underground pipes but not commonly done indoors. It cleans the pipe with a high pressure jet of water, (3,000-4,000 psi), from a multi-port head on the end of a flexible hose. Jetting scours the pipe very clean, but in corroded pipe there is significant risk that the jet can cause a weakened rubber gasket or pipe wall to fail and leak. Because of the risk, jetting is not deemed a feasible action for this project.
   d. Vacuuming: Vacuuming is labor intensive and not commonly done if the pipe condition is sound. It can remove blockage in a clogged pipe if necessary. Waste material is sucked out of a flexible hose, cannot be pushed into a plug, so there is practically no risk of pipe failure or leak. However, the length of pipe vacuumed is limited by the length and flexibility of the vacuum hose, so access will typically involve removing multiple fittings for short runs.
3. Maintenance. Establish and follow an on-going maintenance program for drain and vent pipes from break room sinks:
   a. Do not allow grease, fats, oils or food waste down the drain.
   b. Treat drains with a professional sewer line conditioner with active enzymes, sludge eating bacteria, and plant based solvents such as Total-C, and follow manufacturer's instructions.
   c. Clean sluggish drains as needed.
   d. Spot check pipe slope and support annually.
   e. Video scan pipe interiors every 2-5 years.

f. Spot check pipe wall thickness every 2-5 years.

g. This will reduce congestion and clogged drains in the drainage system, improve flow, and reduce corrosion. The work may occur after hours, will not require demolition or repairs in ceilings and walls, and it will not inconvenience tenants in those areas.

Drawings

Revise record drawings of drain and vent piping from break room sinks to more accurately show as-built conditions and more accurately determine the scope of replacement work.

1. Identify and document routing of existing drain and vent piping from each break room sink back to "Stub for T.I." connections and stacks in core piping.
2. It will take more time and expense for this effort, but the scope of replacement work will be much more accurate, change orders during construction will be reduced, the risk of further damage will be very low, and the disruption to building occupants will be very low. This can occur after hours in a fully occupied building with little or no disruption to tenants.

Replace Drains

Replace drain piping from each break room sink or new kitchen sink, (55 sinks total), in the shortest run feasible back to "Stub for T.I." connections at core where shown on attached plans, (floors 3,4,5,17,21 and 22) as follows:

1. Consult on proper plumbing design.
2. Replace severely damaged pipe with new gray cast iron pipe.
3. Install pipe at a minimum slope of ¼ inch per foot, and provide adequate support per code.
4. Provide independent inspection of all plumbing work performed.
5. Install accessible cleanouts as required for cleaning and maintenance.
6. This will reduce congestion and clogged drains in the drainage system, improve flow, and reduce corrosion. The work will require minor demolition and repairs in ceilings and walls in and around selected break rooms on selected floors, and it will inconvenience tenants in those areas.

Replace Sinks

Replace selected break room sinks with kitchen sinks:

1. Determine where occupant use patterns include food preparation and establish lunch rooms where it is most appropriate to replace bar sinks with kitchen sinks equipped to handle food preparation.
2. Consult on proper plumbing design.
3. Select locations with the shortest run of drain pipe back to the "Stub for T.I." drain connection to ensure adequate slope.
4. Replace severely damaged pipe with new gray cast iron pipe.

5. Install pipe at a minimum slope of ¼ inch per foot, and provide adequate support per code.
6. Provide independent inspection of all plumbing work performed.
7. Install accessible cleanouts as required for cleaning and maintenance.
8. Provide kitchen sinks with accessories to manage food waste and/or keep it out of the sanitary drainage system such as: basket strainers and automatic dishwashers with hot water supply (130°F), which could be delivered by a booster heater. The kitchen sink faucet, however, must have a mixing valve or other means to deliver water at a maximum 110°F to prevent scalding. This will reduce corrosion by providing a regular hot water flush through the dishwasher to reduce build-up of solids, grease and fat in the system. Consider installing garbage disposals at these sinks. Users must be trained on the proper use of a garbage disposal. With a proper water flush after each use, a garbage disposal will reduce the particle size of food waste and increase carry further downstream where higher flows can carry it off site.
9. This will reduce congestion and clogged drains in the drainage system, improve flow, and reduce corrosion. The work will require significant demolition and repairs in walls and casework in and around selected break rooms on selected floors, and it will inconvenience tenants in those areas.

Janitor Sinks:

Clean Pipes

Clean drain and vent pipes from janitor sinks:

1. Clean pipes will slow down the rate of corrosion, improve flow and scouring, and reduce emergency calls for plugged drains and overflows. For details see discussion above under break room sinks, and see discussion of pipe cleaning methodology below.
2. Pipe cleaning methodology. Pipe cleaning method should be appropriate for the condition and access to the pipe, and should only be done by trained, experienced professionals.
   a. Drain Snake: For details see discussion above under break room sinks.
   b. Flushing: For details see discussion above under break room sinks.
   c. Jetting: For details see discussion above under break room sinks.
   d. Vacuuming: For details see discussion above under break room sinks.

Maintenance

Establish and follow an on-going maintenance program for drain and vent pipes from janitor sinks:

1. Do not allow grease, fats, oils or food waste down the drain.
2. Treat drains with a professional sewer line conditioner with active enzymes, sludge eating bacteria, and plant based solvents such as Total-C, and follow manufacturer's instructions.
3. Clean sluggish drains as needed.
4. Spot check pipe slope and support annually.

5. Video scan pipe interiors every 2-5 years.
6. Spot check pipe wall thickness every 2-5 years.
7. This will reduce congestion and clogged drains in the drainage system, improve flow, and reduce corrosion. The work may occur after hours, will not require demolition or repairs in ceilings and walls, and it will not inconvenience tenants in those areas.

Drawings

Revise record drawings of drain and vent piping from janitor sinks to more accurately show as-built conditions and more accurately determine the scope of replacement work.

1. Identify and document routing of existing drain and vent piping from each janitor sink back to stacks in core piping.
2. It will take more time and expense for this effort, but the scope of replacement work will be much more accurate, change orders during construction will be reduced, the risk of further damage will be very low, and the disruption to building occupants will be very low. This can occur after hours in a fully occupied building, but it will be a disruption to tenants.

Replace Drains

Replace drain piping from each janitor sink, (24 sinks total), in the shortest run feasible back to connection to the soil stack at core where shown on record drawings, (floors 1-24), as follows:

1. Remove non-rated wall and ceiling assemblies to expose drain pipe.
2. Replace drain pipe:
3. Consult on proper plumbing design.
4. Replace pipe with new gray cast iron pipe in the shortest run feasible back to stack connections at core where shown on core record drawings.
5. Install pipe at a minimum slope of ¼ inch per foot, and provide adequate support per code.
6. Provide independent inspection of all plumbing work performed.
7. Install accessible cleanouts as required for cleaning and maintenance.
8. This will reduce congestion and clogged drains in the drainage system, improve flow, and reduce corrosion. The work will require minor demolition and repairs in non-rated ceilings and walls in and around selected janitor sinks on selected floors, and it will inconvenience tenants in those areas.

Soil and Vent Stacks:

Clean Pipes

Clean soil and vent stacks:

1. Clean pipes will slow down the rate of corrosion, improve flow and scouring, and reduce emergency calls for plugged drains and overflows. For details see discussion above under break room sinks, and see discussion of pipe cleaning methodology below.
2. Pipe cleaning methodology. Pipe cleaning method should be appropriate for the condition and access to the pipe, and should only be done by trained, experienced professionals. For details on drain snakes, flushing, jetting and vacuuming, see discussion above under break room sinks.

Maintenance

Establish and follow an on-going maintenance program for drain and vent stacks:

1. Do not allow grease, fats, oils or food waste down drains.
2. Treat drains with a professional sewer line conditioner with active enzymes, sludge eating bacteria, and plant based solvents such as Total-C, and follow manufacturer's instructions.
3. Clean sluggish drains as needed.
4. Spot check pipe slope and support annually.
5. Video scan pipe interiors every 2-5 years.
6. Spot check pipe wall thickness every 2-5 years.
7. This will reduce congestion and clogged drains in the drainage system, improve flow, and reduce corrosion. The work may occur after hours, will not require demolition or repairs in ceilings and walls, and it will not inconvenience tenants in those areas.

Drawings

Revise record drawings of drain and vent stacks to more accurately show as-built conditions and more accurately determine the scope of maintenance and/or replacement work. Identify and document routing of existing drain and vent stacks from first floor to roof.

Secure Stacks

Confirm that all drain and vent stack riser clamps are present and secure at each floor. Riser clamp presence must be known prior to work on or replacing any stack sections. It can be determined visually at each floor without disturbing or cutting into walls or floors, and this can occur in a fully occupied building from the top floors down for safety, with little or no disruption to tenants. However, checking clamp tightness will require physical access where the risers meet the slab at each floor. This physical access will likely involve cutting, removing and replacing rated wall assemblies and finishes. This effort is best done in an unoccupied space after hours, and requires a safety check prior to re-occupancy.

Replace Base:

Replace a portion of the two existing horizontal drains at the base of the six inch soil stacks in the first floor restrooms for a proper slope of ¼-inch per foot. The exact length of pipe to replace is yet to be determined but could range from a minimum of 4 feet to a maximum length from stack to street. This will reduce congestion and clogged drains in the drainage system, improve flow, and reduce corrosion. The work may occur after hours, but it will require significant demolition and repairs in the floors and walls, and it will inconvenience tenants and the public in those areas.

Replace Vents:

Replace 4-inch yolk vents with 6-inch yolk relief vents per CPC requirements on floors 4, 9 and 20, and install 6-inch yolk vents on floor 15. This will equalize pressure fluctuations in the drainage system, improve flow, and reduce corrosion. The work will require major demolition and repairs in walls and floors in and around toilet rooms on the above floors, and it will inconvenience tenants in those areas.

Survey Stacks

Determine where soil and vent stacks are "compromised" (on 24 floors), as follows:

1. Measuring pipe wall thickness of the stacks will require physical access to the stacks. Stacks are easily accessible from the restroom ceilings up to the structure above, and this can occur in a fully occupied building with little or no disruption to the tenants. However, scanning stack wall thickness between the floor and ceiling at each level requires access into the plumbing chase, which is eight feet tall, eleven feet wide, 16 inches deep, and is very tight. This will likely involve cutting into non-rated walls, scanning the pipe, replacing the pipe if necessary, and repairing the walls and finishes:
    a. Remove non-rated wall and ceiling assemblies as required to expose pipe and measure wall thickness.
    b. Measure pipe wall thickness of stack in six evenly spaced locations per 10-foot section with ultrasonic thickness scanner, and determine average wall thickness.
    c. If average wall thickness is equal to or greater than ASTM standard minimum, then stack may remain.
    d. Some sections of 6-inch soil and vent stacks scanned in this survey appeared to be compromised, but corrosion damage was variable:
        1) Soil stack corrosion damage appears in the video scans to be significant at floors 11 and 19.
        2) Vent stack corrosion damage was severe at floors 2 and 3.
2. If average wall thickness for that section is less than ASTM standard minimum, (0.15-inches for 6-inch pipe), then stack is compromised and should be replaced or lined (see discussion on pipe liner below):
    a. Replacement:
        1) Where minimum wall thickness is less than ASTM minimum standard, consider pipe is compromised and replace section of stack:
        2) Replace severely damaged pipe with new gray cast iron pipe.
        3) Install pipe, (at a minimum slope of ¼ inch per foot where horizontal offsets occur), and provide adequate support per code.

4) Provide independent inspection of all plumbing work performed.
5) Install accessible cleanouts as required for cleaning and maintenance.
6) This will reduce congestion and clogged drains in the drainage system, improve flow, and reduce corrosion. The work will require major demolition and repairs in ceilings and walls in and around selected toilet rooms on selected floors, and it will inconvenience tenants in those areas.

b. Pipe Liner:

1) Install poly pipe liner inside two 6-inch drain stacks and two 6-inch vent stacks, adapting for all branch connections and fittings. Lining is appropriate for larger pipe sizes that are inaccessible. It will reduce corrosion in the stacks, reduce pipe roughness, and is cost competitive with stack replacement. However, it should only be done by experienced professionals since the liner must have a good bond with the corroded pipe wall or the liner may separate and block flow in the stacks at some point in the future. This work will require physical access to the stacks. Stacks are easily accessible on each floor from the restroom ceilings up to the structure above, and this can occur in a fully occupied building with little or no disruption to the tenants. However, adapting branch connections between the floor and ceiling at each level will require access through cleanouts in the lateral piping. The plumbing chase containing the stacks is 8 feet tall, eleven feet wide, 16 inches deep, and very tight. This may require cutting into non-rated walls, installing cleanouts, and repairing the walls and finishes.

3. Where minimum wall thickness is equal to or greater than ASTM minimum standard, consider pipe is not compromised and reposition existing drain pipes that are not sloped properly:

a) Reposition any existing soil and vent pipes that will remain as required, (horizontal offsets in soil stacks need a proper slope of ¼-inch per foot). This will reduce congestion and clogged drains in the drainage system, improve flow, and reduce corrosion. The work may occur after hours, but it will require demolition or repairs in ceilings and walls in a few areas, and it will inconvenience tenants in those areas.

Screen Vents

Install four screened caps, such as Elmdor/Stoneman 1550 cast iron vandal resistant counter flashing on the four 6-inch stacks above the roof. These will minimize entry of pests into the sanitary sewer system, but will need annual maintenance to prevent mud, dust or debris from restricting airflow.

Building Maintenance Standards

Develop and implement a building standards document, specifically for the proper maintenance, installation and design of existing plumbing piping and any future plumbing piping in the building. Require review of this by any plumbing contractors working in the building.

Recommendations:

For further explanation of the following recommendations, refer to Options section above.

First Priority

Break Room Sinks:

1. **Food Waste.** Stop putting food waste into break room sinks.
2. **Clean Pipes.** Clean drain and vent pipes serving break room sinks.
3. **Maintenance.** Establish and follow an on-going maintenance program.
4. **Drawings.** Revise record drawings of drain and vent piping serving break room sinks.
5. **Replace Drains.** Replace drain piping from each break room sink or new kitchen sink.

Janitor Sinks:

1. **Clean Pipes.** Clean drain and vent pipes serving janitor sinks.
2. **Maintenance**. Establish and follow an on-going maintenance program.
3. **Drawings**. Revise record drawings of drain and vent piping serving janitor sinks.
4. **Replace Drains.** Replace drain piping from each janitor sink.

Soil and Vent Stacks:

1. **Clean Pipes.** Clean soil and vent stacks.
2. **Maintenance.** Establish and follow an on-going maintenance program.
3. **Drawings.** Revise record drawings of soil and vent stacks.

Second Priority

Break Room Sinks

1. **Replace Sinks.** Replace selected break room sinks with kitchen sinks.

Stacks

1. **Secure Stacks.** Confirm that soil and vent riser clamps are secure at each floor.
2. **Replace Base.** Replace poorly sloped drains at base of soil stacks.
3. **Replace Vents.** Replace existing four inch joke vents, on the 4th, 9th and 20th floors, with six inch yoke vents, and install new six inch yoke vents on the 15th floor.
4. **Survey Stacks.** Determine where soil and vent stacks are compromised.
5. **Replace or Line**. Replace or Line compromised stacks.

Third Priority

Vents

Screen Vents. Install screened caps with counterflashing on four six-inch roof vents.

Maintenance Standards

Maintenance Standards: Develop and implement a building standards document, specifically for the proper maintenance, installation and design of existing plumbing piping and any future plumbing piping in the building. Require review of this by any plumbing contractors working in the building.

Peer Review

A peer review was conducted by Cal Laws:

Calvin Laws, P.E., CEO, M15040
Laws and Associates, Inc.
1801 Murchison Drive, Suite 160
Burlingame, CA 94010
P: 650 697 5691

Mr. Laws' comments were as follows:

We have reviewed your report and can honestly say it is very well done and the extent of the investigation is impressive. The following are some items for consideration. These are not new ideas that you have not already covered in your report, but maybe additions to your ideas:

1. **Is the user the problem?** In regards to the sink piping; would it be possible to create a time line for when the TI work was completed; for when the tenant starting using the sink and who the tenant was. This was perhaps the cause of clogging and corrosion conditions existed. Since most of the sink piping was installed as TI work, most of the piping probably became clogged and/or corroded very soon after installation or the tenant started using the sink. Knowing who the tenant was could allow a better idea of how to correct the problem.

2. **Is the piping installation the problem?** Also in regards to sink piping, most plumbing contractors would not install waste piping with little or no slope, however the contractor may have been forced to the existing piping arrangement because ceiling space was probably not available for proper slope at the time the TI work was installed. Therefore, since the ceiling space conditions have certainly not improved since original installation of plumbing, sprinklers and HVAC systems, has consideration been given to installation of a vacuum waste system to replace the gravity sink waste system?.. This system can be installed with no slope or even go up and over ductwork, etc.

3. **Is the sink the problem?** All new sink should be supplied with a strainer and a container. The container can be used for collecting food waste collected by the strainer. This waste can be

disposed of with the building's sanitary garbage. Food waste discharged by a garbage disposer into the waste piping will exacerbate the amount of food waste collected in the waste piping.

4. **Is corrosion the problem?** It should be clarified that soil piping is manufactured to a standard with a minimum and maximum allowable wall thicknesses, when the wall thickness is measured to be equal or smaller than the minimum wall thickness allowed by the manufacturer's standard, it does not mean that the pipe is corroded, it may have been manufactured to that wall

Mr. Laws' comments have been acknowledged and incorporated into this report as appropriate as follows:

1. The user is part of the problem. BOE has been the original and only tenant since 1992, when it was built. BOE will need to be part of the solution.

2. The piping installation is part of the problem. With 24 floors and many POCs we think pipe replacement can be properly sloped, vented, and rerouted around existing utilities to new POCs if necessary without a vacuum waste system. Correcting slope and vent are part of the solution.

3. The sink is part of the problem. If food waste cannot be kept out of sinks we suggest bigger sinks, basket strainers, dishwashers, hot water, and garbage disposals should be considered.

4. Corrosion is definitely part of the problem. All pipe observed was US made to ASTM standard minimum/maximum wall thickness, except one fitting from China that replaced one of the MTL Report samples that failed. We cannot be certain how thin the pipe was originally, but the lab work shows graphitic corrosion has damaged the iron, reduced pipe wall thickness and increased roughness in most of the drain pipe samples. Lining and/or new smoother pipe need to be part of the solution.

Draft Review

The draft report was reviewed by the following DGS and BOE staff: Andre Arnold, Vince Paul, Bob Courtnier and Nik Karlsson.

Preparation and Limitations

Limitations

The services of Interactive Resources are provided in a manner we believe to be consistent with the prevailing standard of care. This report is neither comprehensive nor exhaustive and is based on limited observations of the project, limited exploratory demolition, review of documents cited and discussions with individuals listed. The information is for the exclusive use of the client to whom this is addressed.

Interactive Resources does not warrant or guarantee the performance of any in-place or future construction on this project, whether or not it incorporates any of the recommendations contained herein.

Preparation

This report was prepared by Mike Southworth, PE, LEED AP CxA and reviewed and edited by Thomas K. Butt, FAIA, LEED AP BD+C. It was peer reviewed by Calvin Laws, PE.

Licensed Architect California C7389
Licensed General Contractor California 290922

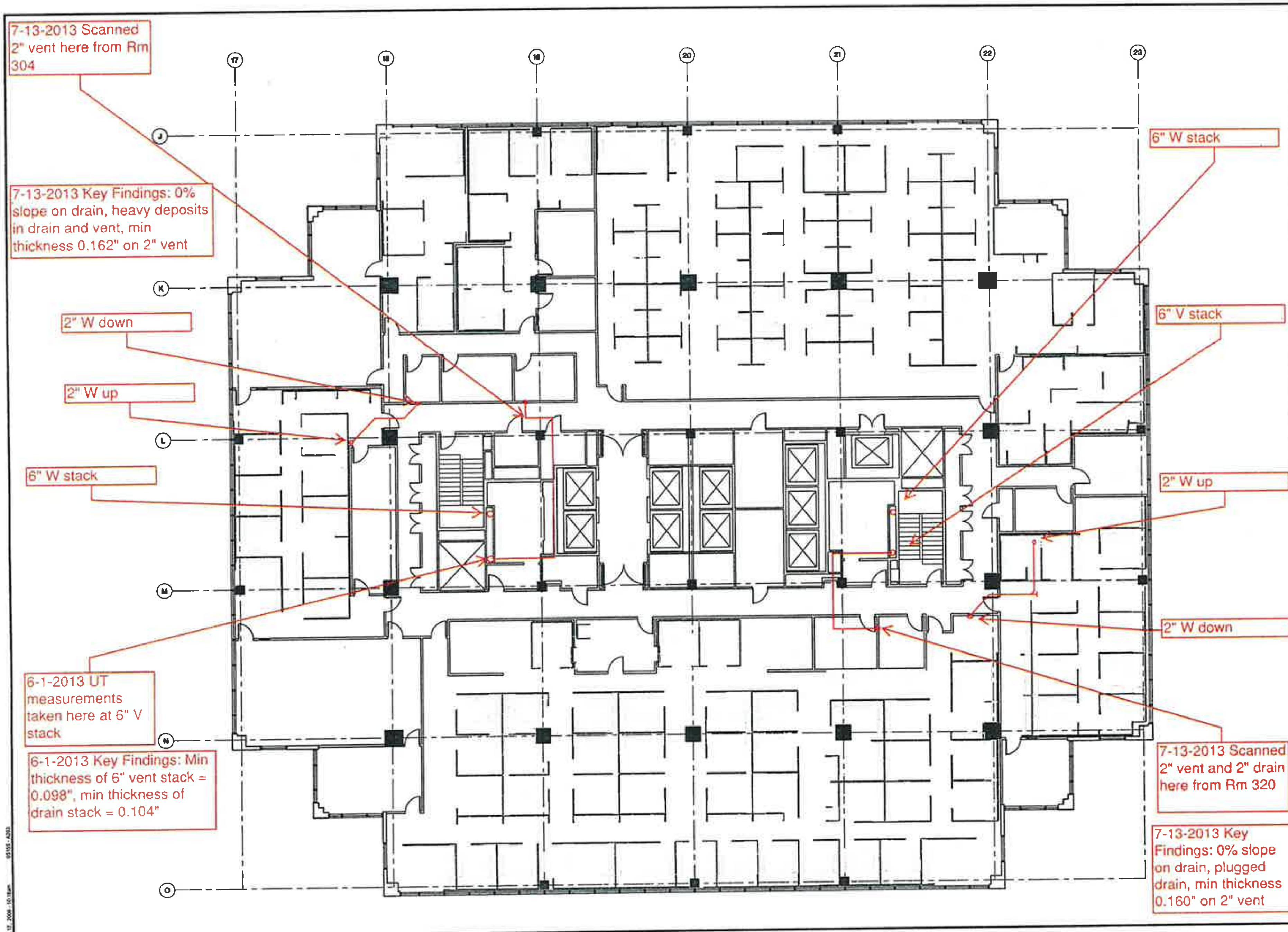
Appendix A – Summary of Dates, Activities and Findings

Legend: 0=none or excellent, 1=minimum or good, 2=moderate or fair, 3=severe or poor

BOE investigation findings

	Date	Location	Columns	Waste, in	Vent, in	Sample	Sample #	Deposits	Visible Signs of Corrosion	Loss of Wall Thickness	Slope	Support	Routing per record drawings	pH	Fixtures Served	Activities	Observations
1	4/8/2013	Roof	L-18	6		None		1	2				3		All	Video	Many more fittings and offsets in W&V stacks than shown on record drawings
		Roof	L-18		6	None		1	1				3				Down 105 ft
		Roof	M-22	6		None		1	2				3		All	Video	Many more fittings and offsets in W&V stacks than shown on record drawings
		Roof	M-22		6	None		1	1				3				Down 30 ft
2	4/26/2013	24th Mens	M-21		6	Fitting		2	2						All	Video	Vent good, vent branch quantity consistent with dwgs
		24th Mens	M-21	6		Fitting		3	3							Video	Variable corrosion damage in waste, good to poor at 19th and 11th floors
		24th Mens	M-21	6		Hor pipe	22								All		
3	5/11/2013	24th Wom	M-19		6	Hor pipe	21	2	1						All	Video	Vent in good condition, 24th to 11th floors
		24th Wom	M-19	6				2	2						All	Video	Waste good above 24th, in fair condition 24th to 11th
		24th Wom	M-19	6						0					All	UT gauge	Waste wall measured 0.26 max to 0.22 min
4	5/18/2013	14th Mens	M-21	2		Hor pipe	20			0					Sinks	UT gauge	Waste wall measured 0.182 max to 0.177 min
		19th Janitc	L-19		2										Sinks	UT gauge	Vent measured 0.184 max to 0.156 min
5	6/1/2013	14th Wom	M-19		3	Hor pipe	23										
		14th Wom	M-19	6				2	2		3				All	Video	Waste stack fair, but standing water at base at 1st floor
		14th Wom	M-19		6	Vert pipe		2	3						All	Video	Variable corrosion damage in vent, fair to poor at 2nd and 3rd floors
		10th Janitc	L-19	3?				3	3		3				All	Video	Waste has standing water, heavy debris
		3rd Wome	M-19	6						3					All	UT gauge	Vent wall measured 0.205 max to 0.098 min
		3rd Wome	M-19		6	Vert pipe				3					All	UT gauge	Waste wall measured 0.221 max to 0.104 min
6	6/8/2013	5th	L-18	2		Fitting	18	3	3	1	3	3	3	6	Sinks		
		5th	L-18	2				3	3				3		Sinks	Video	Waste has standing water, heavy debris, insects, tubercles
		5th	L-18		2			3	3					4.5	Sinks	Video	Vent has heavy deposits, scale and tubercles, blocking 1/3 of pipe
		4th	L-18	2		Hor pipe	19			1	3		3		Sinks		Short sweep bend in horizontal, un-banded rubber couplings
		4th	L-18	2		Hor pipe									Sinks	Video	Waste sections have variable signs of corrosion
		5th	L-18		2					0					Sinks	UT gauge	Vent wall measured 0.195 max to 0.190 min
7	6/15/2013	5th	M-22	2		Hor pipe	17			2	3	3	3		Sinks	UT gauge	Waste wall measured 0.236 max to 0.140 min
		5th	M-22	2		Hor pipe		3	3					6	Sinks	Video	Waste has heavy soft deposits, standing water
		5th	M-22	2		Fitting									Sinks		
		10th	L-19	2		Hor pipe				1	1				Sinks	UT gauge	Waste wall measured 0.212 max to 0.147 min
		10th	L-19	2		Hor pipe		3			1	1			Sinks	Video	Waste was too plugged with debris
		10th	L-19		2	Hor/Vert pipe								6	Sinks	Video	Vent had heavy debris and many insects
8	6/22/2013	17th	L-19	2		Hor pipe	14	3	3	3	3	1	1		Sinks	UT gauge	Waste wall measured 0.176 max to 0.105 min
		17th	M-21	2		Hor pipe	15	3	3				1		Sinks	Video	Waste was too plugged with debris
9	6/29/2013	21st	L-21	2		Fitting	11	3		1	3		3	5	Sinks	UT gauge	Waste wall measured 0.170 max to 0.136 min
		21st	L-21	2		Hor pipe		3						5	Sinks	Video	Waste has heavy debris, standing water
		21st	M-22	2		Fitting	12	3		3			3	6	Sinks	UT gauge	Waste wall measured 0.210 max to 0.114 min
		21st	M-22	2		Hor pipe	10	3		3	3		3		Sinks	Video	Waste was too plugged with debris
		21st	L-19	2		Fitting		3					1		Sinks		
		21st	L-19	2		Hor pipe	13	3					1		Sinks	UT gauge	Waste wall measured 0.170 max to 0.098 min
		21st	L-19		2	Hor pipe		0	0					6	Sinks		
10	7/6/2013	22nd	M-21		2	Fitting	6						3		Sinks	UT gauge	Waste: 0.174-0.138
		22nd	M-21		2	Hor pipe	7			1	3		3		Sinks	UT gauge	Vent: 0.209-.192
		22nd	M-21	2		Hor pipe									Sinks	Video	Waste: plugged with debris
		22nd	M-21		2	Hor pipe									Sinks	Video	Vent: clean, some scale
		22nd	N-22	2		Hor pipe	5				3		2	5.6	Sinks		
		22nd	M-18	2		Hor pipe	8		1		3		3	5	Sinks	Video	Waste: scale and debris, standing water
		22nd	M-18	2		Hor pipe			3						Sinks	UT gauge	Waste: 0.178-0.112
		22nd	M-18		2	Vert pipe			1						Sinks	Video	Vent: clean, some scale
		22nd	K-18	2		Fitting	9		2		1		3	5.5	Sinks	Video	Waste: scale and debris, standing water
		22nd	L-19	2		Hor pipe			1		1		2		Sinks	UT gauge	Waste: 0.168-0.131
		22nd	L-19		2	Hor pipe					1		2		Sinks	UT gauge	Vent: 0.199-.174
		22nd	L-19	4		Hor pipe			1		1		1		Sinks	Video	Waste: minimal debris, good condition
11	7/13/2013	3rd	L-19		2	Hor pipe	4	3					0		Sinks	Video	Vent had heavy debris and many insects
		3rd	L-19		2	Hor pipe			1		1				Sinks	UT gauge	Vent: 0.209-.162
		3rd	M-21		2	Hor pipe	3						0		Sinks	Video	Vent had heavy debris and many insects
		3rd	M-21		2	Hor pipe		3	1		1				Sinks	UT gauge	Vent: 0.189-.161
		3rd	M-21	2		Vert pipe		3						5	Sinks	Video	Waste: plugged with debris
		4th	L-18		2	Hor pipe	2	3			3		0	4.5	Sinks	Video	Vent had heavy, wet debris and many insects
		4th	L-18	2		Fitting	1	3	1				0		Sinks		

Appendix B – Floor Plans



450 N STREET

BOARD OF EQUALIZATION
SACRAMENTO, CA

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Seal:

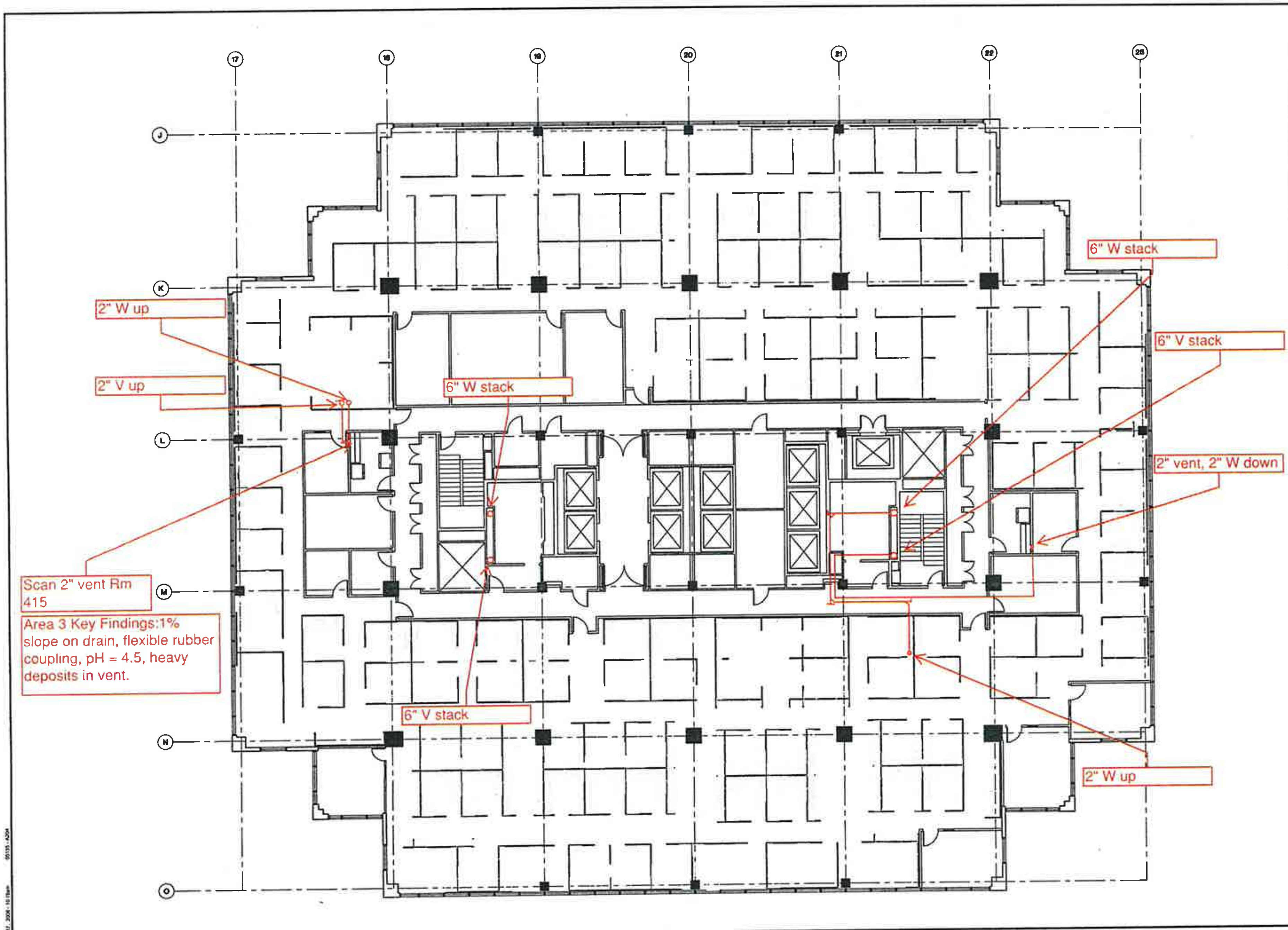
NO.	DESC.	DATE

Sheet Title:
THIRD FLOOR PLAN

Investigation Plan 6-1-2013 and 7-13-2013

Date: 01.03.06
Drawn: BG
Checked: RR

A203



450 N STREET

BOARD OF EQUALIZATION
SACRAMENTO, CA

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Seal:

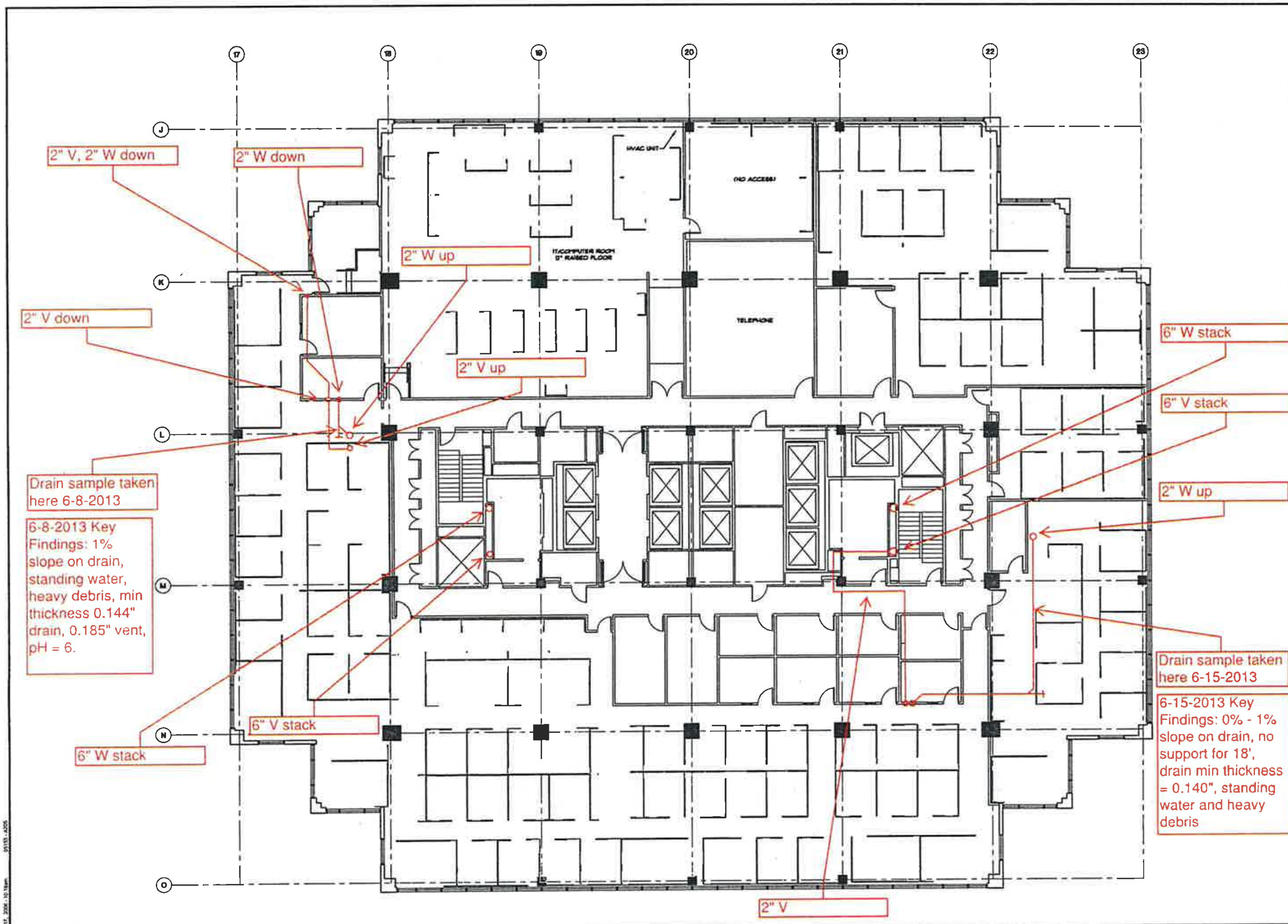
NO	DESC	DATE

Sheet Title:
FOURTH FLOOR PLAN

Investigation Plan
7-13-2013

Scale:	1/8" = 1'-0"
Project #	05155.00
Date:	01.03.06
Drawn:	BG
Checked:	RR

A204



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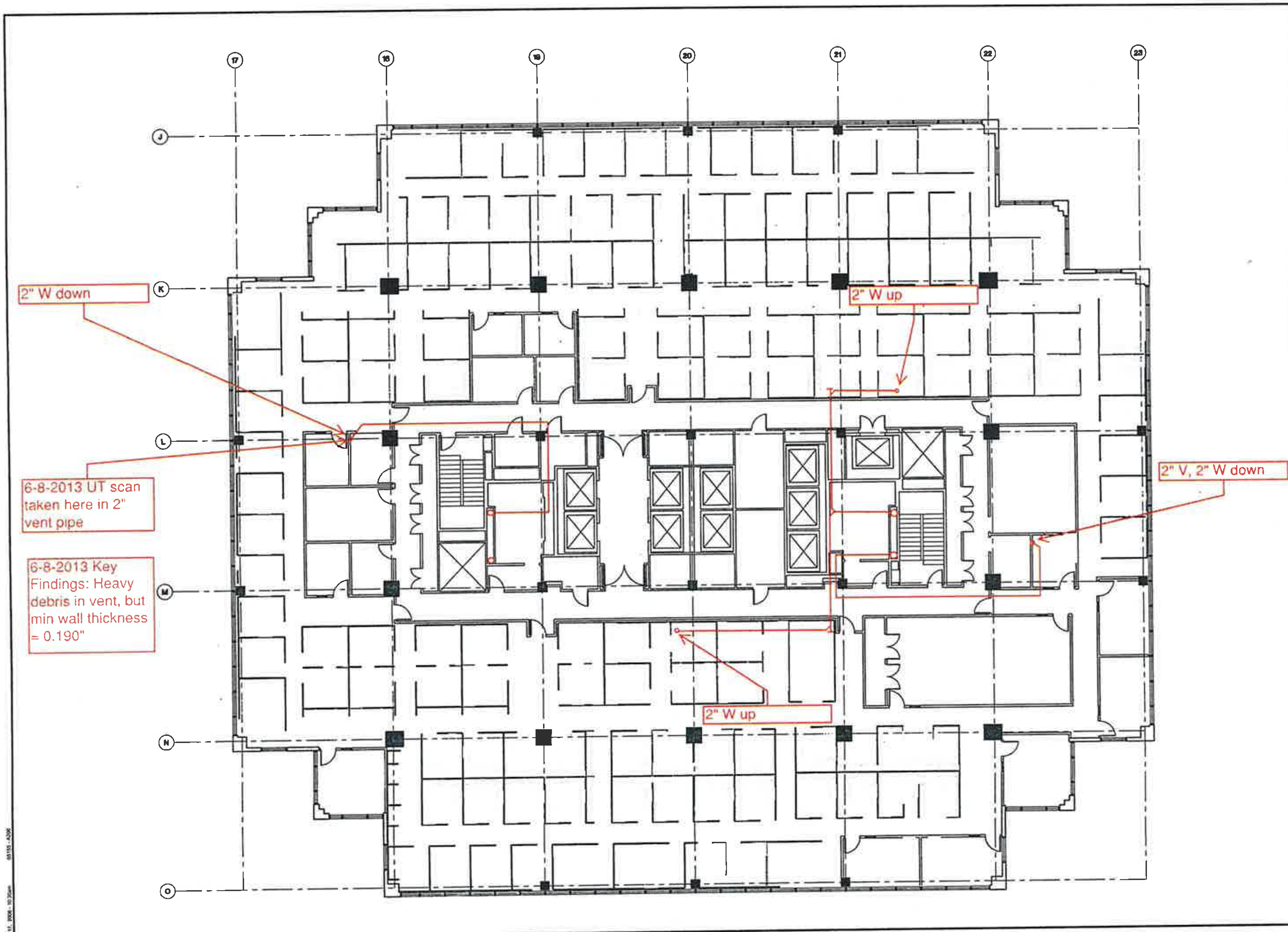
Sheet Title:
FIFTH FLOOR PLAN

Pipe Investigation Plan 6-8-2013 and 6-15-2013

A205



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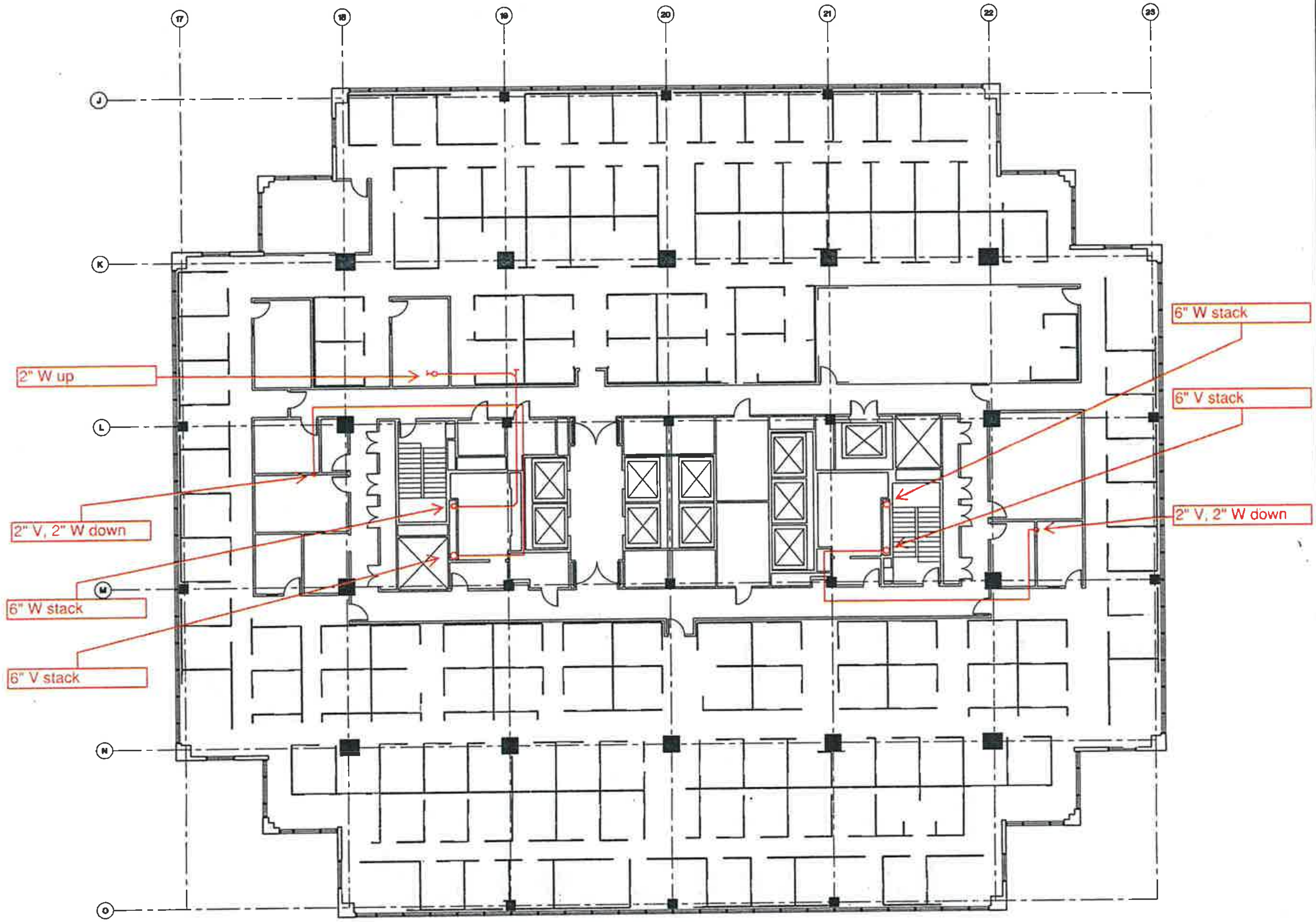
Sheet Title:

SIXTH FLOOR PLAN

Pipe Investigation Plan 6-8-2013

Scale:	1/8" = 1'-0"
Project #	05155.00
Date:	12.22.05
Drawn:	RR
Checked:	JC

A206



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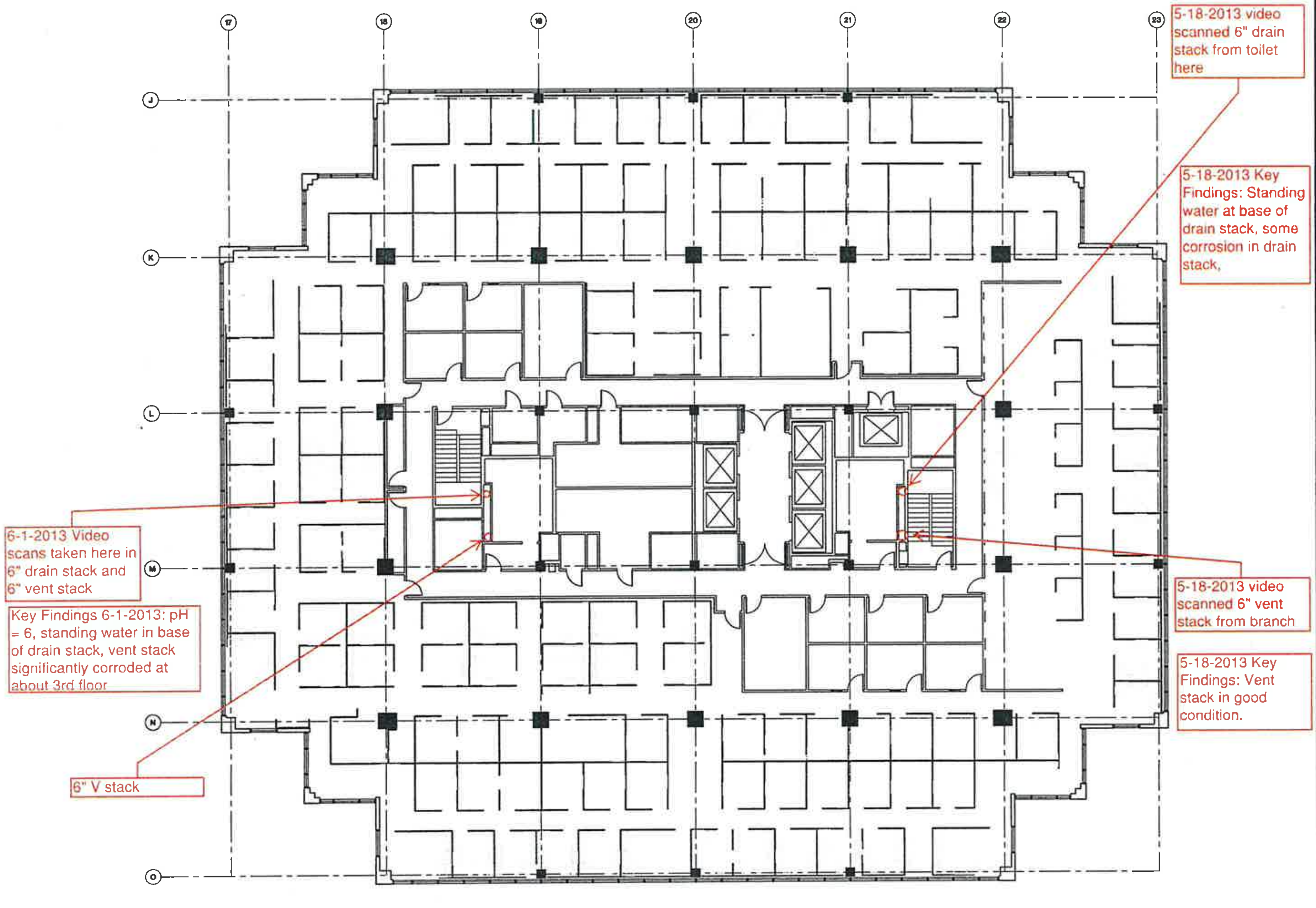
Sheet Title:
TENTH FLOOR PLAN

Pipe Investigation Plan 6-15-2013

Scale:	1/8" = 1'-0"
Project #	05155.00
Date:	01.03.06
Drawn:	BG
Checked:	RR

A210



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Seal:

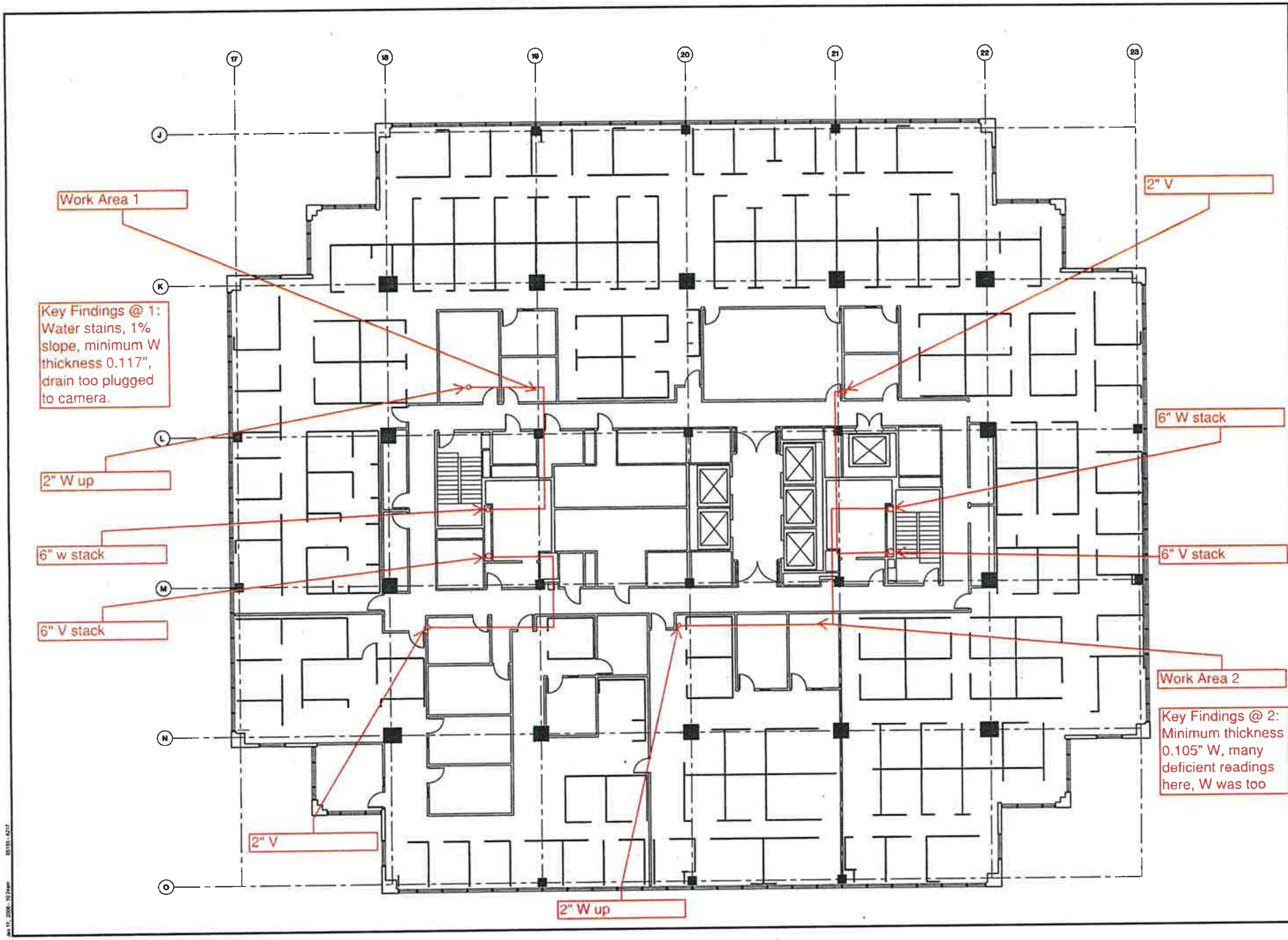
NO	DESC	DATE

Sheet Title:
FOURTEENTH FLOOR PLAN

Investigation Pla
5-18-2013 and
6-1-2013

Project #	05155.00
Date:	01.03.06
Drawn:	BG
Checked:	RR

A214



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Seal:

NO	DESC	DATE

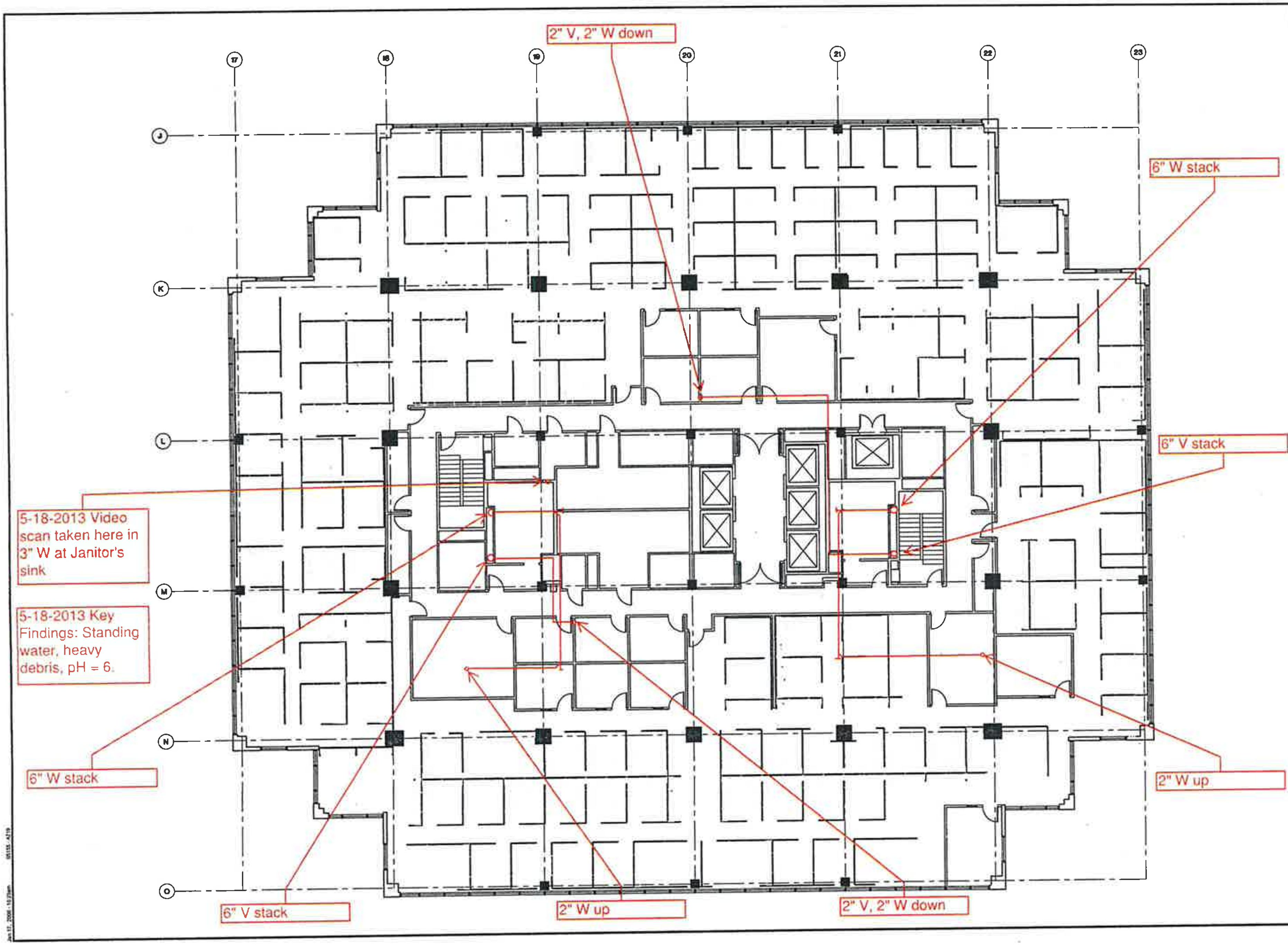
Sheet Title:

SEVENTEENTH FLOOR PLAN

Pipe Investigation Plan 6-22-2013

Scale:	1/8" = 1'-0"
Project #	05155.00
Date:	01.03.06
Drawn:	BG
Checked:	RR

A217



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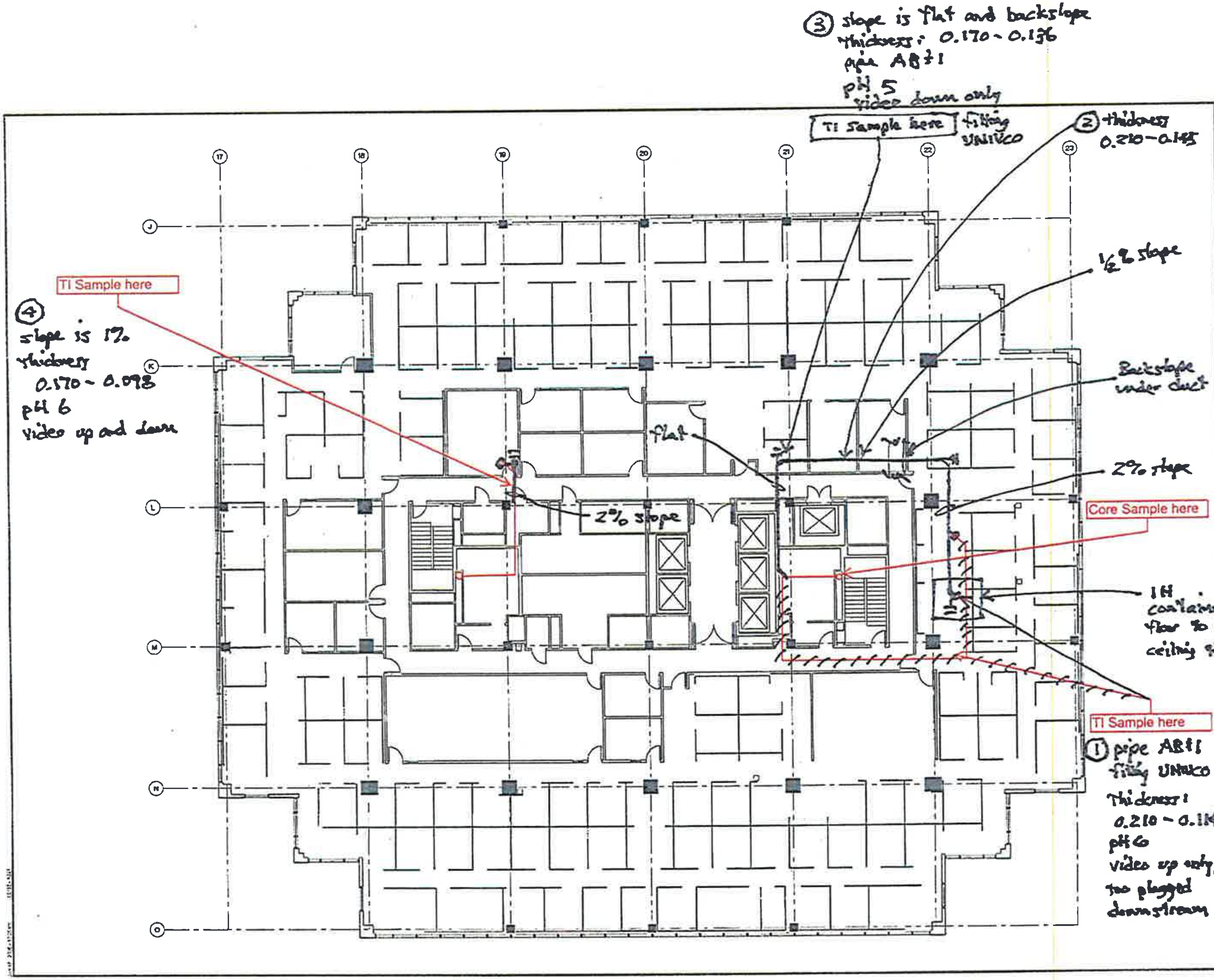
NO	DESC	DATE

Sheet Title:
NINETEENTH FLOOR PLAN

Pipe Investigation Plan 5-18-2013

Date: 01.03.06
Drawn: BG
Checked: RR

A219



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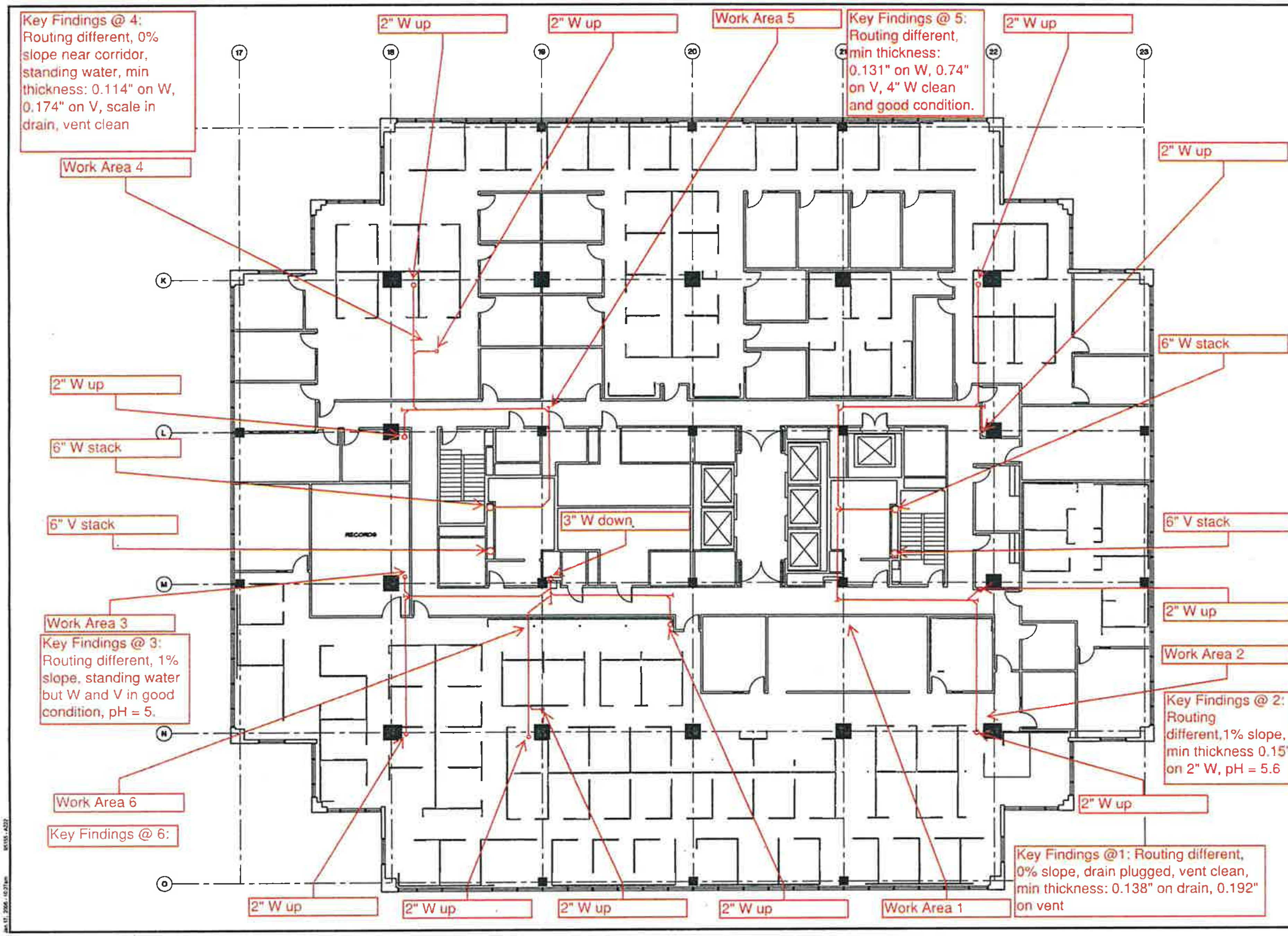
TWENTY FIRST FLOOR PLAN

Pipe Investigation Plan

Scale:	1/8" = 1'-0"
Project #:	05155.00
Date:	01.03.00
Drawn:	DG
Checked:	RR

A221



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Seal:

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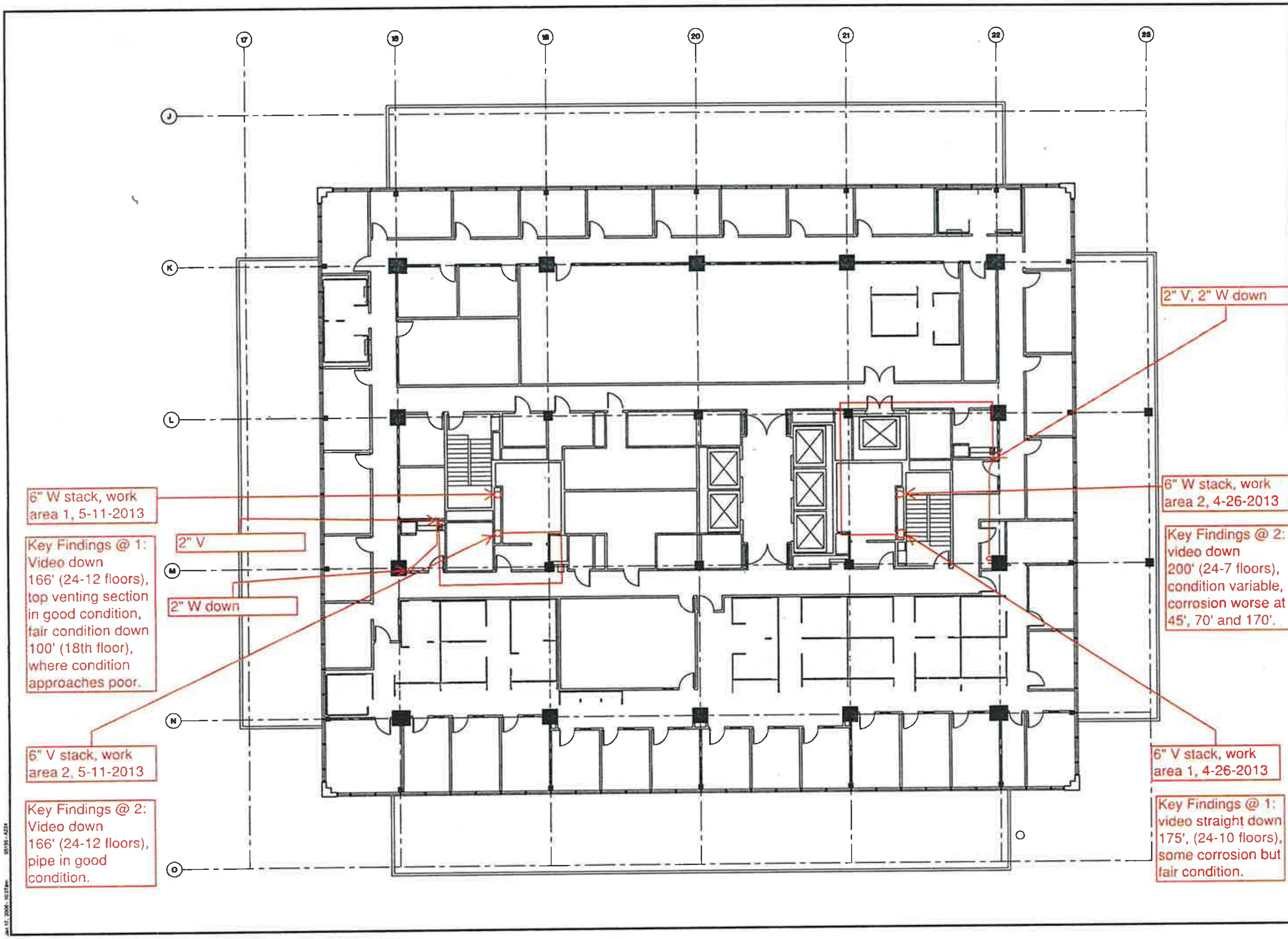
Sheet Title:
TWENTY SECOND FLOOR PLAN

Pipe Investigation Plan 7-6-2013

Scale:	1/8" = 1'-0"
Project #	05155.00
Date:	01.03.06
Drawn:	BG
Checked:	RR

A222



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NO.	DESC.	DATE

Sheet Title:
TWENTY FOURTH FLOOR PLAN

Pipe Investigation Plan 4-26-2013 and 5-11-2013

Drawn: BG
Checked: RR

A224

Appendix C – TEI Report

TESTING ENGINEERS, INC.

Quality Assurance Services
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August 12, 2013

~~WINZLER & KELLY~~ GHD
2235 Mercury Way, Suite 150
Santa Rosa, CA 95407

Lab. No.: 7D83

ATTENTION: Mr. Mike Southworth, P.E.

SUBJECT: Evaluation of Sink Drainage Piping for Extent and Cause of Corrosion.
450 N Street, Sacramento, California.

Dear Mr. Southworth;

At your request, we have performed an evaluation of the subject cast iron piping system at the above referenced location.

SCOPE

The scope of our work was to perform onsite thickness measurement of the piping at selected locations, and perform laboratory testing of a number of representative pipe samples to verify the extent of corrosion and possible causes.

PROCEDURES & RESULTS

1. Pipe Wall Thickness Measurements

The pipe wall thickness was measured using a calibrated Model CMX-DL ultrasonic thickness gauge manufactured by Dakota Ultrasonics. The gauge was set to obtain measurements on cast iron materials. The results and test locations are presented in Table 1.

2. Visual Examination

The pipe samples removed from the sink drainage and vent systems during our onsite inspection were visually examined, documented, and photographed in our laboratory. The samples were documented in the as received condition initially. This was followed by cutting the pipe sections axially to observe their interior condition before and after removal of the built-up deposits when present. Table 2 represents detailed description of the samples and corresponding observations. Photos 1 through 63 depict various views of each pipe sample.

3. Laboratory Thickness Measurements

Cross sections of pipe samples that had indicated corrosion were polished and visually examined to determine the extent of corrosion. The loss in wall thickness was measured with a fine scale having 1/64" increments. The original wall thickness was also determined from an area without corrosion for reference. The results are presented in Table 2. These measurements indicated loss in pipe wall thickness of as much as 77%. The macrographs corresponding to thickness measurement data are presented in Photos 64 through 77.

4. Microstructural Evaluation

The cross section specimens used in section 3 were polished down to a 6 micron finish and examined at high magnification with an optical microscope in the un-etched condition.

The unetched specimens exhibited randomly oriented fine graphite flakes. This was typical of all samples examined, although there were slight variations in the amount and size of the flakes (Photos 78 through 87). The dark porous areas on the cross sections are evidence of corrosion that has resulted in graphitization (Photos 78, 81, 83, and 84). This will be discussed in more detail later in this report.

There is also evidence of presence of porosity (dark spots) away from corroded areas, which is inherent in most cast irons.

5. Chemical Analysis of Pipe Samples

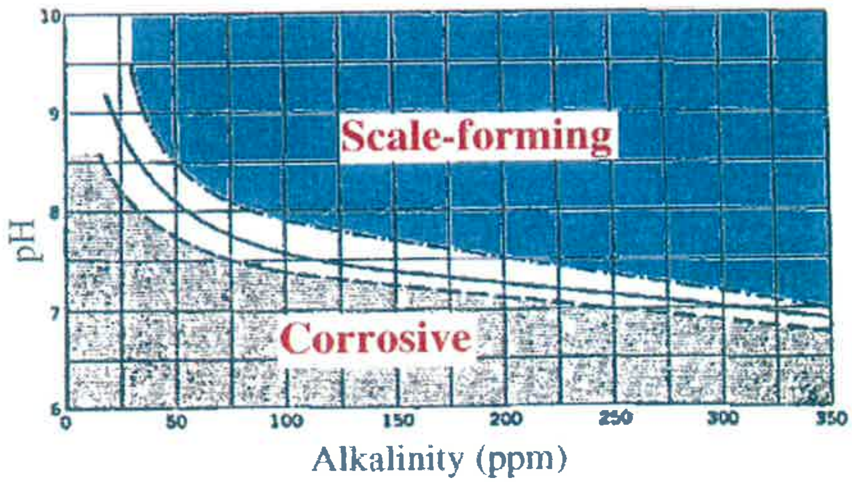
Specimens from each of TEI pipe sample numbers 5 and 16 (representing minimal and severe corrosion) were removed and analyzed for their chemical composition. The results are presented in Table 3. Based on these results, both samples have very similar compositions and meet the general chemical requirements for gray cast iron outlined in ASTM A888 (Hubless Cast Iron Soil Pipe and Fittings for Sanitary & Storm Drain, Waste, and Vent Piping Applications).

6. Water Analysis

Water samples taken from 5th floor sink faucet and 1st floor janitor's room were analyzed for corrosive tendencies by determining the Langlelier Saturation Index (LSI) of the water. If the actual pH of the water is below the calculated saturation pH (pHs), the LSI is negative and the water has a very limited scaling potential and would have corrosive tendencies. If the actual pH exceeds pHs, the LSI is positive, and being supersaturated with calcium carbonate, the water has a tendency to form scale and

Water Analysis (cont'd)

would not have corrosive tendencies. At increasing positive index values, the scaling potential increases and the corrosive tendency is reduced. Based on the water analysis, the calculated LSI was –1.38 and -1.53 for the 5th floor faucet and janitors room, respectively. This is indicative of the water having low to moderate corrosive tendencies. Please see the graph and notes below for a general relationship between pH and alkalinity as it relates to corrosion. The Langelier index takes into account both these variables.



The graph above is known as the Baylis Curve. It shows the relationship between pH, alkalinity, and water stability. Water above the lines is scale-forming while water below the lines is corrosive. Stable water is found in the white area between the lines.

7. Analysis of Deposits

Sections of four of the pipe samples were analyzed to determine the chemical make- up of their surfaces. The analysis was performed by "Energy Dispersive X-ray" (EDX). The results are presented in Figures 1 through 6. This analysis indicated the interior surface of the pipes to be rich in iron oxide (rust). In addition, there was evidence of various levels of sulfur and in one instance (pipe sample 8) small amounts of chlorine present. The areas with the thick dark layer on the surface of the pipe, the surface contained higher amounts of carbon (Figures 4 and 6).

The analysis of the deposits removed from the interior of the pipe sections indicated primarily the same data as the pipe samples (Figures 7 through 14). The exception was the higher amounts of chlorine on two of the samples (Figures 9 and 11). In general the

Analysis of Deposits (cont'd)

amount of carbon within the deposits was less than the carbon on the pipe surfaces, but the sulfur content was higher.

DISCUSSION & CONCLUSIONS

The general condition of piping appears satisfactory. However there were measurements on pipes examined in our laboratory that indicated losses as much as 77% of the wall thickness on waste piping. The laboratory thickness measurements in the corroded area were obtained on the completely clean section of the pipe and did not include the graphitized or partially graphitized material that was still intact. The thickness readings on the intact areas of the pipe sections were also measured and recorded as reference. The vent piping is in good overall condition as indicated by the field and laboratory measurements. Some the most severe corrosion was observed on the ends of the waste pipe sections. Details of the readings are outlined in Table II.

The properties of the cast iron pipe reported above, is typical of cast iron piping material. Gray cast iron inherently contains porosity, but there was no evidence of excessive porosity in the sections examined, which may lead to premature leaking of pipes. Chemical analysis of two pipe sections representing good and corroded conditions indicated both sections meet the ASTM A888 chemical requirements. The graphite distribution in the samples examined exhibited random orientation and uniform distribution of fine graphite (Type A).

The metallographic examination of cross sections of corroded pipes indicated graphitization which is a typical feature observed on corroded gray (graphitic) cast iron. Images of various stages of graphitization have been documented and presented in this report.

Observations of the interior of the pipe on the laboratory samples indicated built up of deposits to varying degrees in the waste piping. The sources of these deposits are more than likely the food residue from the sinks that has accumulated in the pipes. In addition, the by-products of corrosion of the pipes, as reported, contribute to the build-up deposits. EDX analysis of these deposits exhibited high levels of oxygen and iron indicative of iron oxide (rust), as would be expected. In addition, various levels of sulfur and carbon were found within the deposits and on corroded surfaces. This is evidence of decaying organic matters resulting in sulfur containing compounds, which are generally corrosive. The bacterial colonies from the organic matters on pipe walls accelerate corrosion below them due to oxygen cell concentration. The moisture trapped within the deposits and not able to readily evaporate contributes to this corrosion. The corrosion rate may be accelerated further by the carbon dioxide from the bacteria, which can combine with water to become carbonic acid and accelerate corrosion.

The presence of chloride on some of the pipes as presented earlier is an additional factor promoting corrosion.

DISCUSSION & CONCLUSIONS (cont'd)

The water analysis described in section 5 of this report indicate water that has moderate corrosive tendencies with slightly negative Langelier Index. However, the water chemistry effect on corrosivity in this instance should be minimal due the heavy levels of deposits, which block the deposition of the calcium carbonate protective layer on the pipe.

In our opinion, the primary cause of corrosion of the piping is through a graphitization mechanism of the cast iron, which is caused by the deposits accumulated in the waste piping during a period of over 20 years. The mechanical and design issues related to the piping will be addressed in the final report prepared by GHD.

If you have any questions regarding this report or if we may be of further assistance, please contact the undersigned at (510) 835 3142 X199.

Respectfully Submitted;
TESTING ENGINEERS, INC.

Hossein Arbabi, Ph.D., P.E.
Senior Metallurgical Engineer

Add column for pipe size

Add column for waste or vent

On-site Observations

Add column with corrosion rank, 1-4

Table I – ~~Ultrasonic Thickness Measuremen`t Data~~

Pipe Description	Inspection Date	Location - Floor No.	Thickness Readings, inches
3" Vent Pipe – Horiz.	5/18/13	14	0.180, 0.182, 0.179, 0.172
3" Vent Pipe – Vert.	5/18/13	14	0.200, 0.215, 0.195, 0.191
6" Waste Pipe – Horiz.	5/18/13	14	0.182, 0.177, 0.180, 0.175
6" Waste Pipe – Vert.	6/1/13	M-19, 3rd Floor	0.120, 0.221, 0.180, 0.104
6" Vent Pipe – Vert.	6/1/13	M-19, 3rd Floor	0.111, 0.098, 0.160, 0.205
4" Waste Pipe – Horiz.	6/1/13	M-19, 3rd Floor	0.206
2" Waste Fitting – Vert.	6/1/13	M-19, 3rd Floor	0.176
2" Vent Fitting – Vert.	6/1/13	M-19, 3rd Floor	0.210
2" Waste Pipe – Horiz.	6/1/13	M-19, 3rd Floor	0.162
2" Vent Pipe – Horiz.	6/1/13	M-19, 3rd Floor	0.217
2" Waste Pipe – Horiz.	6/8/13	L-18, 5th Floor	0.144, 0.188, 0.157, 0.190
2" Vent Pipe – Horiz.	6/8/13	L-18, 5th Floor	0.188, 0.190, 0.185, 01.85
2" Waste Pipe – Horiz.	6/8/13	L-18, 4th Floor	0.203, 0.189, 0.192, 0188
2" Vent Pipe – Horiz.	6/8/13	L-18, 4th Floor	0.161, 0.188, 0.139, 0175,
2" Vent Pipe – Horiz.	6/8/13	L-18, 6th Floor	0.195, 0.195, 0.190, 0.193
2" Waste Pipe – Horiz.	6/15/13	M-22, 5th Floor	0.236, 0.190, 0.157, 0.140
2" Waste Pipe – Horiz.	6/15/13	L-19, 10th Floor	0.147, 0.157, 0.192, 0.177
2" Waste Pipe – Horiz.	6/22/13	L-19, 17th Floor	0.117, 0.159, 0.126, 0.138
2" Waste Pipe – Horiz.	6/22/13	M-22, 17th Floor	0.105, 0.143, 0.165, 0.176
2" Waste Pipe – Horiz.	6/29/13	M-22, 21st Floor	0.114, 0.116, 0.128, 0.120
2" Waste Pipe – Horiz.	6/29/13	L-21, 21st Floor	0.145, 0.155, 0.179, 0.175
2" Waste Pipe – Horiz.	6/29/13	L-22, 21st Floor	0.158, 0.161, 0.165, 0.136
2" Waste Pipe – Horiz.	6/29/13	L-19, 21st Floor	0.112, 0.098, 0.129, 0.142
2" Waste Pipe – Vert.	6/29/13	L-19, 21st Floor	0.154, 0.155, 0.148, 0.149
2" Waste Pipe – Horiz.	7/6/13	M-21, 22nd Floor	0.115, 0.138, 0.174, 0.148
2" Vent Pipe – Horiz.	7/6/13	M-21, 22nd Floor	0.205, 0.209, 0.195, 0.192
2" Waste Pipe – Horiz.	7/6/13	N-22, 22nd Floor	0.180, 0.158, 0.174, 0.150
2" Waste Pipe – Horiz.	7/6/13	M-18, 22nd Floor	0.207, 0.187, 0.210, 0.193
2" Waste Pipe – Vert.	7/6/13	M-18, 22nd Floor	0.173, 0.163, 0.159, 0.175
2" Waste Pipe – Horiz.	7/6/13	K-18, 22nd Floor	0.178, 0.165, 0.175, 0.112
2" Waste Pipe – Horiz.	7/6/13	L-19, 22nd Floor	0.165, 0.131, 0.168, 0.157
4" Waste Pipe – Horiz.	7/6/13	L-19, 22nd Floor	0.186, 0.140, 0.180, 0.145
2" Vent Pipe – Horiz.	7/6/13	L-19, 22nd Floor	0.193, 0.176, 0.199, 0.174
2" Vent Pipe – Horiz.	7/13/13	L-19, 3rd Floor	0.162, 0.172, 0.205, 0.202
2" Vent Pipe – Horiz.	7/13/13	M-21, 3rd Floor	0.168, 0.180, 0.161, 0.189
2" Vent Pipe – Vert.	7/13/13	L-18, 4th Floor	0.151, 0.156, 0.191, 0.188
2" Waste Pipe – Vert.	7/13/13	L-18, 4th Floor	0.191, 0.187, 0.184, 0.180

Correct decimals

Add column for pipe size

Add column for waste, vent

Add column with corrosion rank, 1-4

Add column with build-up rank, 1-4

Table II – Laboratory Observations

TEI Sample No.	Sample Type	Location	Date Sampled	Observations	Laboratory Thickness Measurements, inch	Overall Views Photo No.	Macrographs Photo No.	Macrographs Photo No.
1	Fitting, vent	4th Floor, L-18	7/13/13	Minimal Corrosion/ Moderate Build Up	N/A	1 ,2, 3, 4	N/A	N/A
2	6" long pipe, horiz. vent	4th Floor, L-18	7/13/13	Minimal to Moderate Corrosion/Severe Build Up	Intact - 0.172 Corroded - 0.094	5, 6, 7, 8	64	78, 79
3	3" long pipe, horiz. vent	3rd Floor, M-21	7/13/13	Moderate Corrosion/ Moderate Build Up	N/A	9, 10, 11	N/A	N/A
4	3" long pipe, horiz. vent	3rd Floor, L-19	7/13/13	Minimal corrosion, severe corr. on edge, moderate build up	Intact – 0.172 Corroded – 0.063 (on edge)	12, 13, 14, 15	65, 66	80
5	22" long pipe, horiz. waste	22nd floor N-22	7/6/13	Minimal corrosion and build up	Intact – 0.187	16, 17,	67	81
6	Fitting, vent	22nd floor M-21	7/6/13	Minimal corrosion, dark thick build up	N/A	18, 19, 20	68	82
7	18" long pipe, horiz. vent	22nd floor M-21	7/6/13	No corrosion, coating intact	N/A	21, 22	N/A	N/A
8	12" long pipe, vert. waste	22nd floor M-18	7/613	Moderate corrosion and build up, severe edge corrosion	Intact - 0.156 Corroded – 0.109	23, 24, 25	69	83
9	Fitting, waste	22nd floor K-18	7/6/13	Severe Corrosion, severe black build up	Intact – 0.203 Corroded – 0.047	26, 27, 28	70, 71	84
10	12" long pipe, horiz. waste	21st floor M-22	6/29/13	Minimal corrosion, moderate to severe build up	N/A	29, 30, 31	N/A	N/A
11	Fitting, waste	21st floor M-21	6/29/13	Minimal corrosion, severe build up	N/A	32, 33, 34	N/A	N/A
12	Fitting, waste	21st floor M-22	6/29/13	Minimal/moderate corrosion,	Intact - 0.187 Corroded – 0.109	35, 36, 37	72, 73	85
13	24" long pipe, horiz. waste	21st floor L-19	6/29/13	Moderate corrosion, moderate/severe build up	N/A	38,39, 40	N/A	N/A
14	12" long pipe, 45° slope, waste	17th floor, L-19	6/22/13	Moderate/severe corrosion and moderate build up	N/A	41, 42, 43	N/A	N/A
15	12" long pipe, 45° slope, waste	17th floor, M-22	6/22/13	Moderate Corrosion/Severe Build Up	Intact - 0.156 Corroded -0.078	44, 45, 46	74, 75	86

OK, on 6/1/13
I seem to have
overwritten COC for
this sample.

Table II – Laboratory Observations (cont'd)

TEI Sample No.	Sample Type	Location	Date Sampled	Observations	Laboratory Thickness Measurements, inch	Overall Views Photo No.	Macrographs Photo No.	Macrographs Photo No.
16	26" long pipe, horiz. waste	5th floor, M-22	6/15/13	Moderate/severe corrosion and build up	Intact – 0.164 Corroded – 0.063	47, 48, 49	76, 77	87
17	30" long pipe, horiz. waste	5th floor, M-22	6/15/13	Moderate/severe corrosion and build up	N/A	47	N/A	N/A
18	Fitting, waste	5th floor L-18	6/8/13	Minimal corrosion and build up	N/A	50, 51, 52	N/A	N/A
19	13" long pipe, horiz. waste	4th floor, room 416	6/8/13	Severe corrosion, moderate/severe build up	N/A	53, 54, 55	N/A	N/A
20	6.5" long pipe, horiz. vent	14th floor, men's room	5/18/13	No corrosion, no build up	N/A	56, 57	N/A	N/A
21	14.5" long 6" pipe, horiz. vent	~~22th floor~~ women's room	5/11/13	No corrosion, no build up	N/A	58, 59	N/A	N/A
22	6" long 6" pipe, horiz. waste	24th floor, men's room	4/27/13	Minimal Corrosion, no build up	N/A	60, 61	N/A	N/A
23	7" long pipe, horiz. ~~waste~~	~~3rd floor~~ women's room	6/1/13	No corrosion, no build up	N/A	62, 63	N/A	N/A

24th floor per COC

14th floor per COC

vent per COC

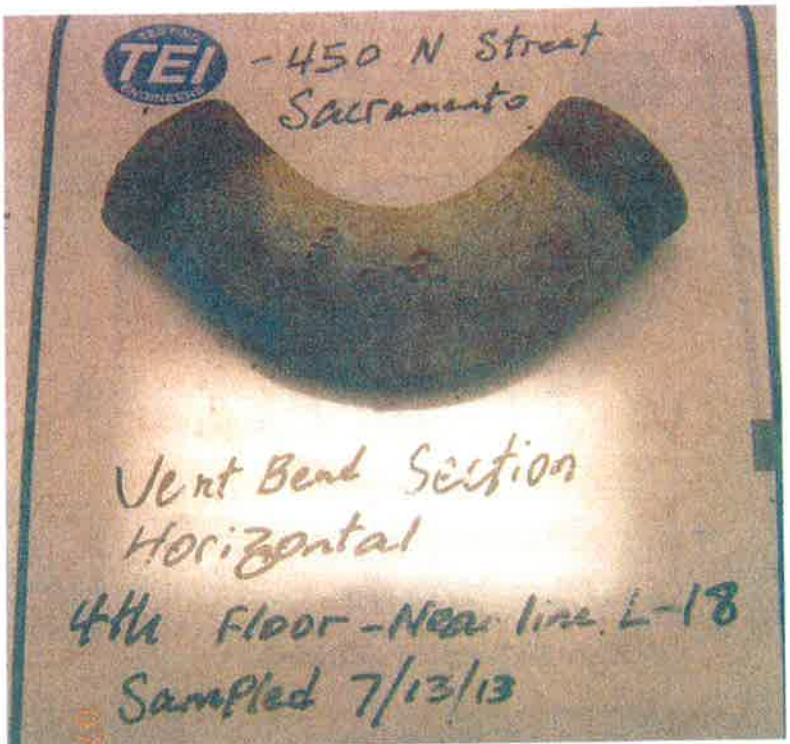


Photo 1- Sample 1

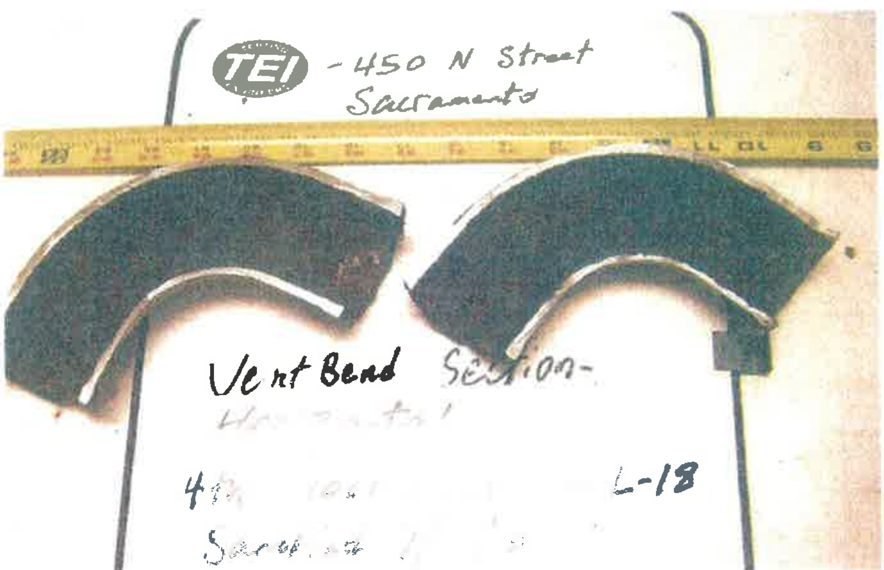


Photo 2 – Sample 1 – Interior

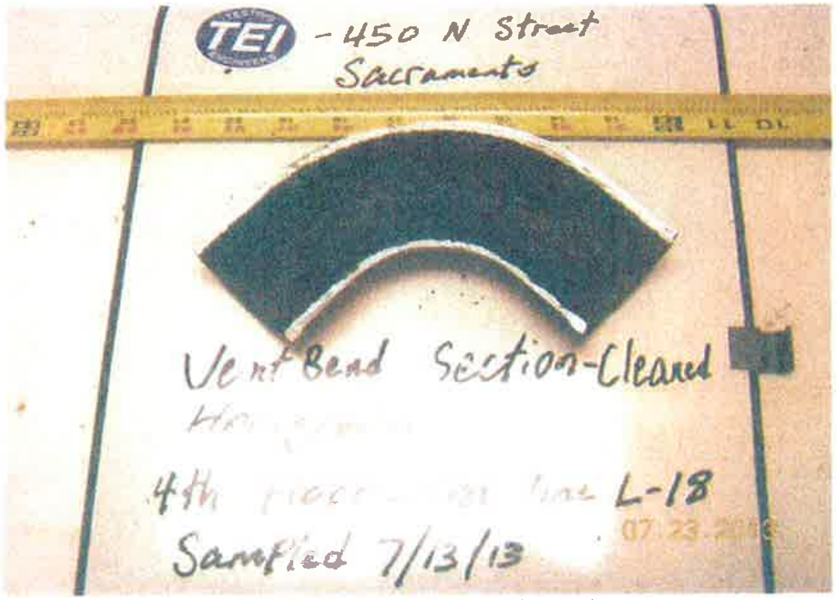


Photo 3 – Sample 1 - Cleaned

Photo 4 – Sample 1 – Cleaned – Close-Up

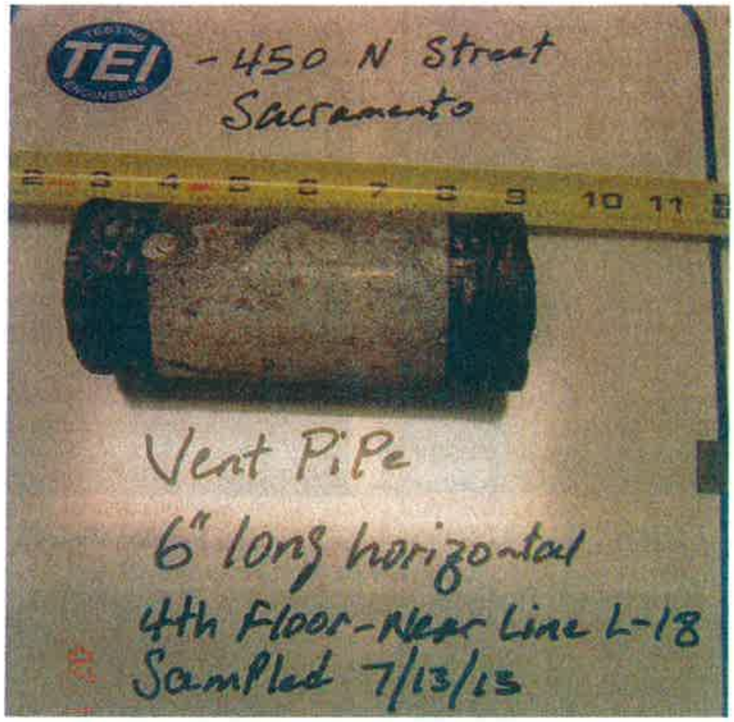


Photo 5 - Sample 2

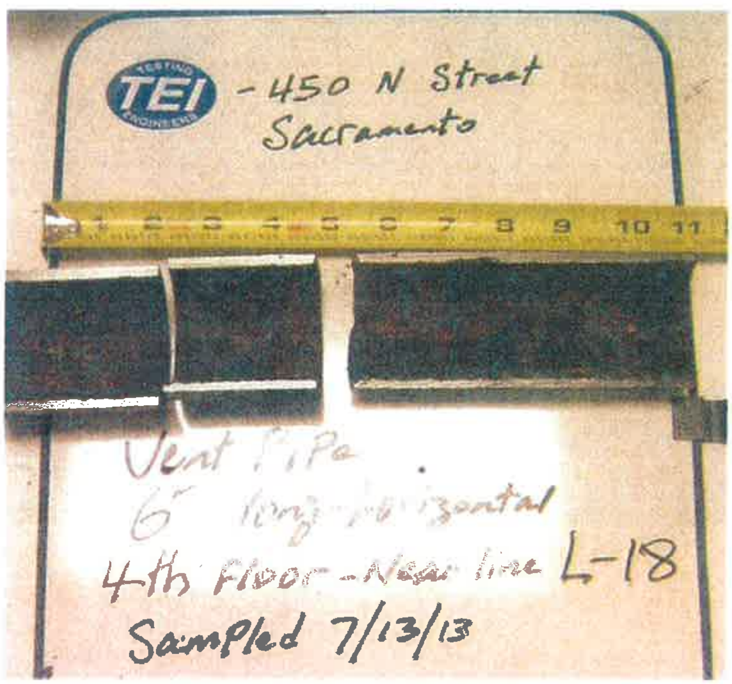


Photo 6 – Sample 2 - Interior

Photos 7a and 7b – Sample 2 – Cross Section and Interior Views

Photo 8 – Sample 2 – Interior - Cleaned

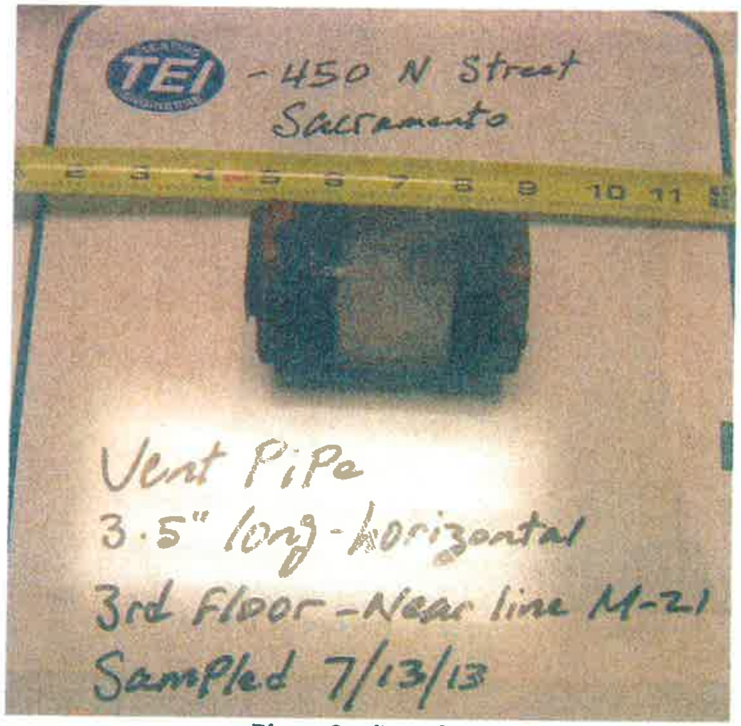


Photo 9 - Sample 3

Photo 10 – Sample 3 – Interior

Photo 11 – Sample 3 - Interior - Cleaned

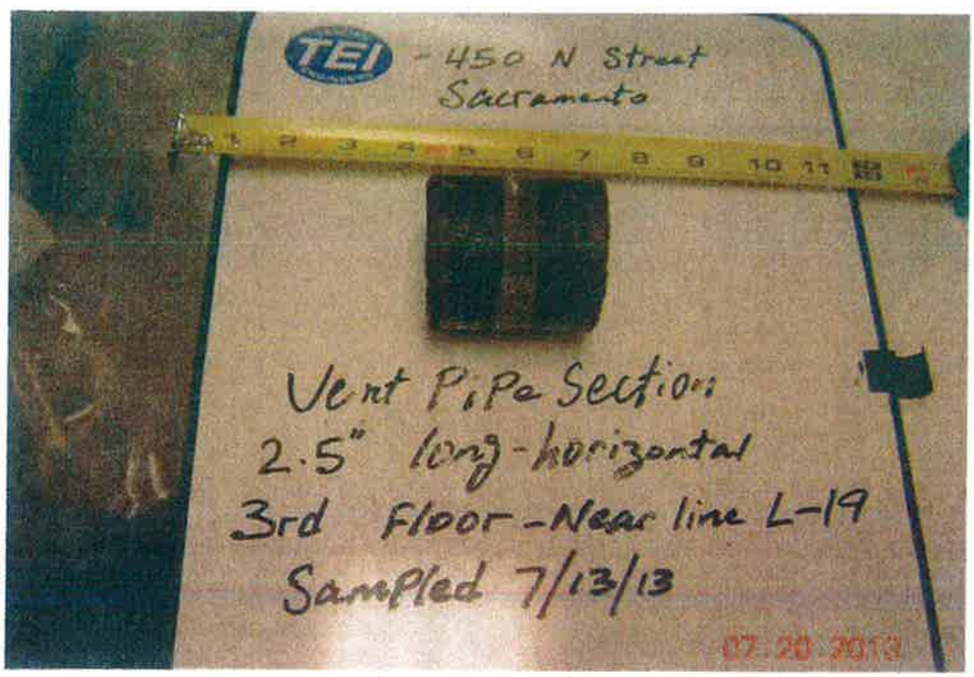


Photo 12 – Sample 4

Photo 13 – Sample 4 – Interior

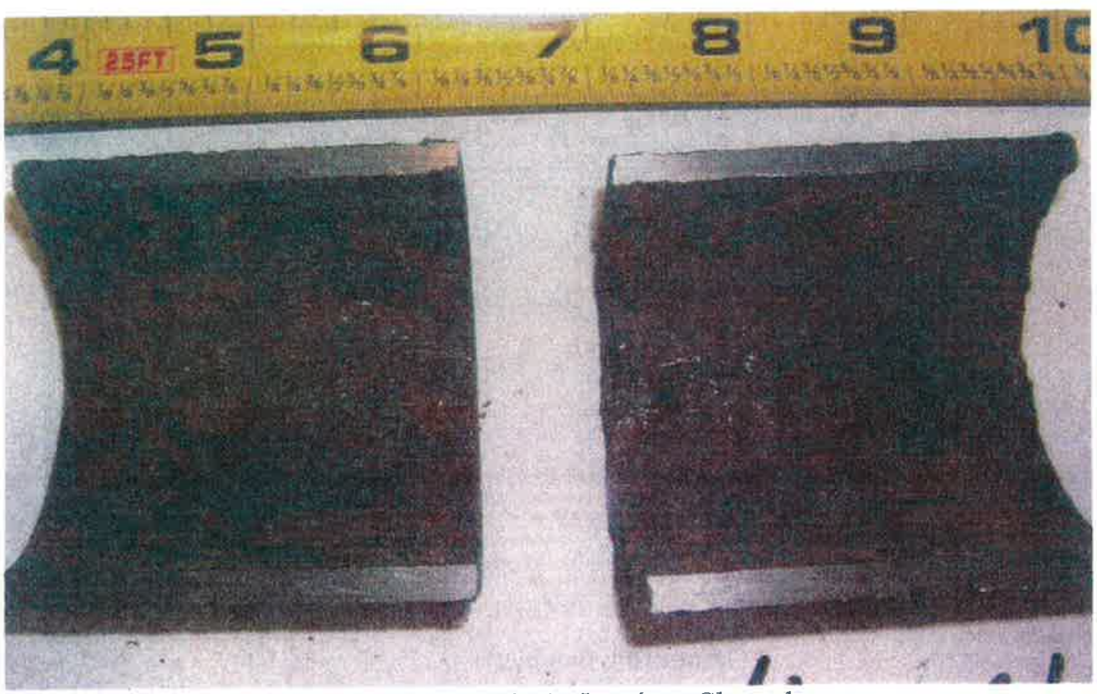


Photo 14 - Sample 4 - Interior - Cleaned

WINZLER & KELLY GHD

Photo 15 - Sample 4 – Edge Corrosion

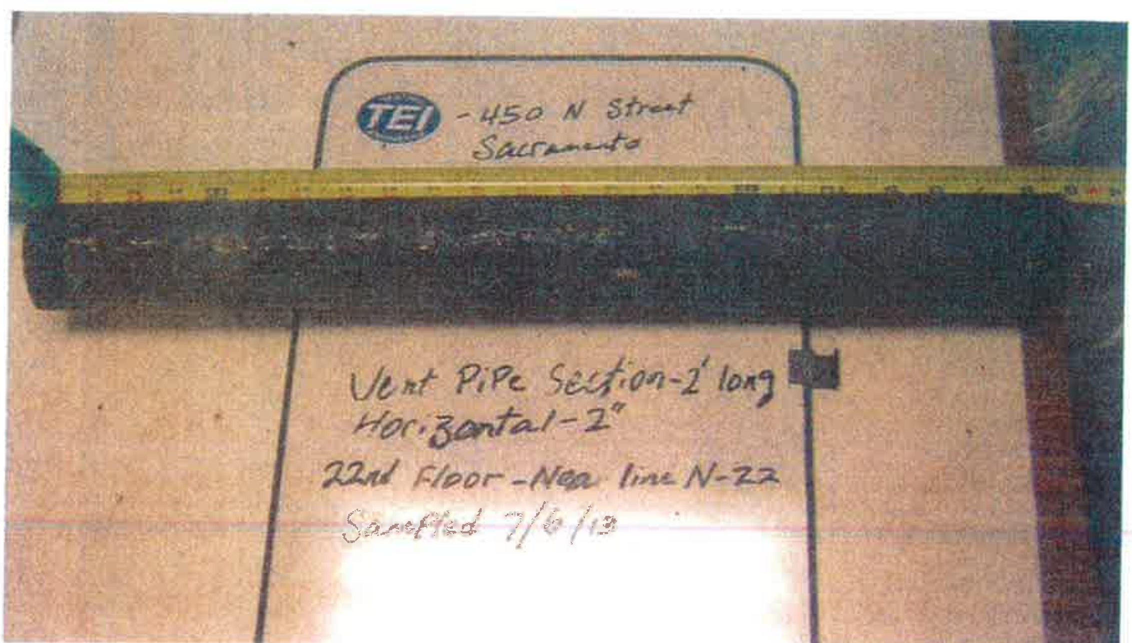


Photo 16 – Sample 5

Photo 17 – Sample 5 – Interior

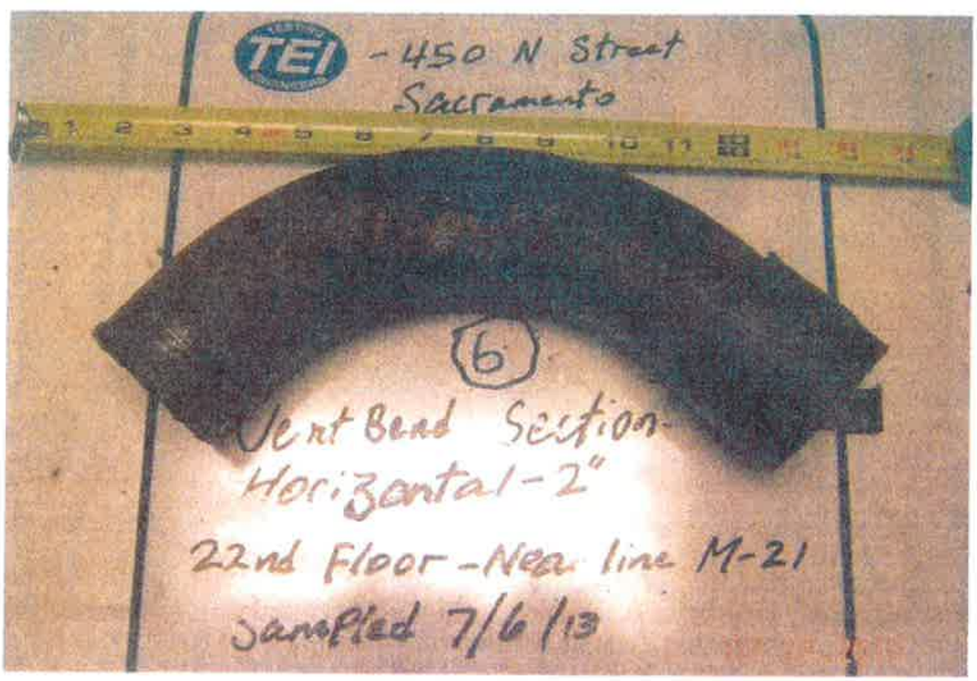


Photo 18 – Sample 6

Photo 19 – Sample 6 - Interior

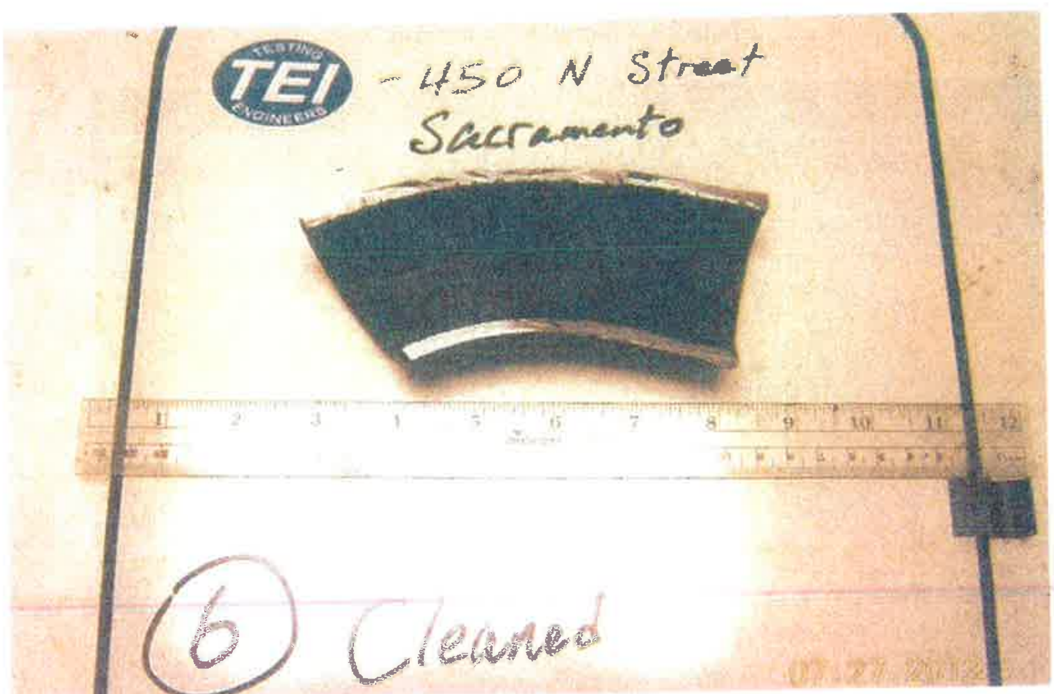


Photo 20 – Sample 6 – Interior - Cleaned

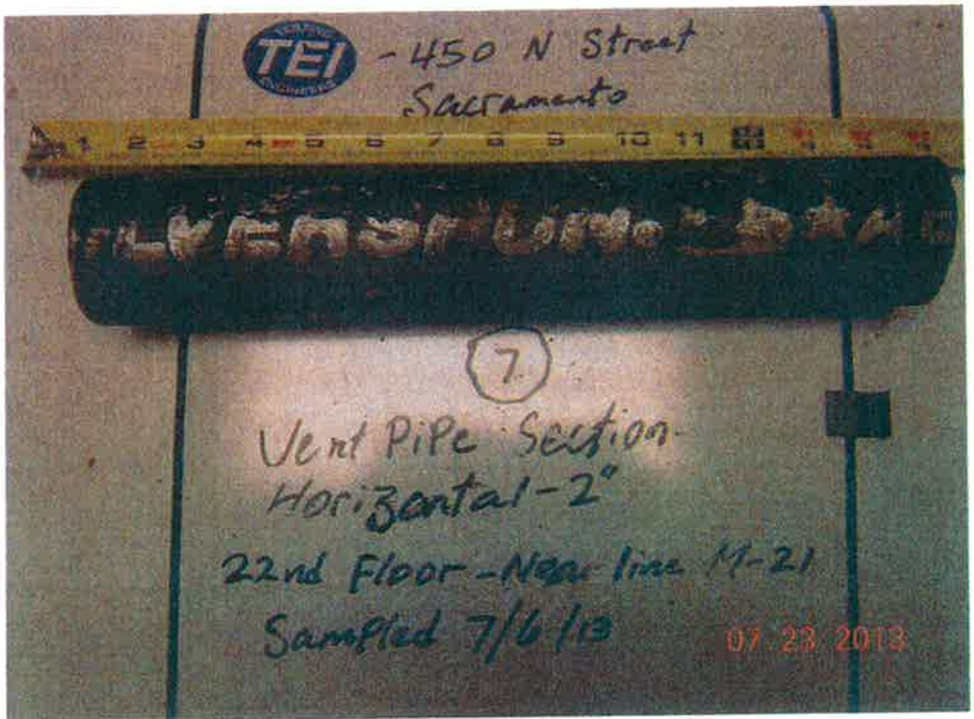


Photo 21 – Sample 7

Photo 22 – Sample 7 - Interior

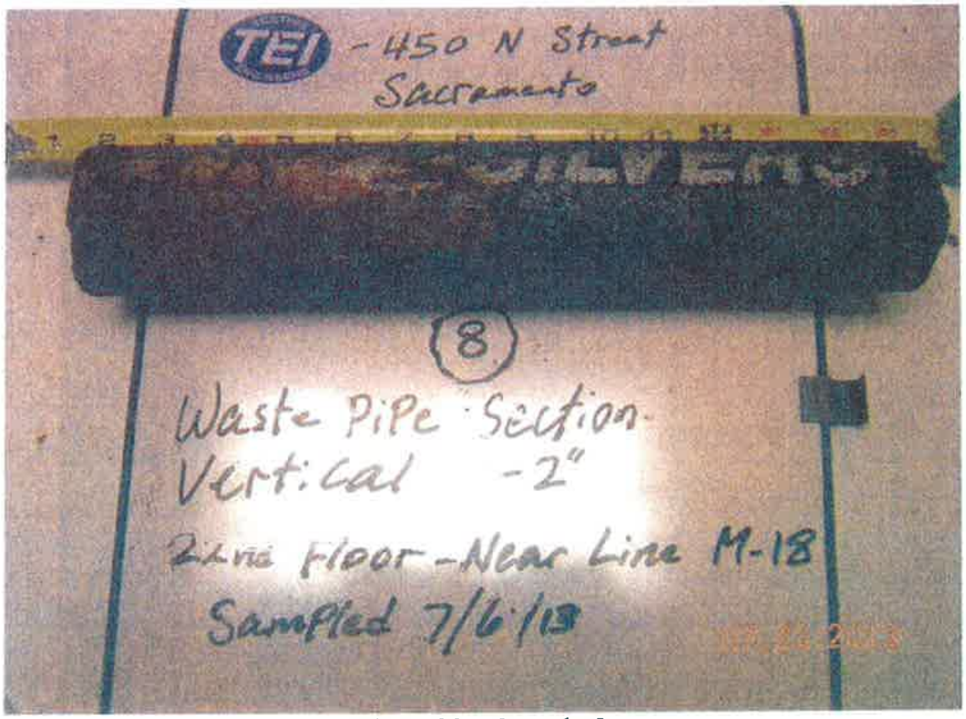


Photo 23 – Sample 8

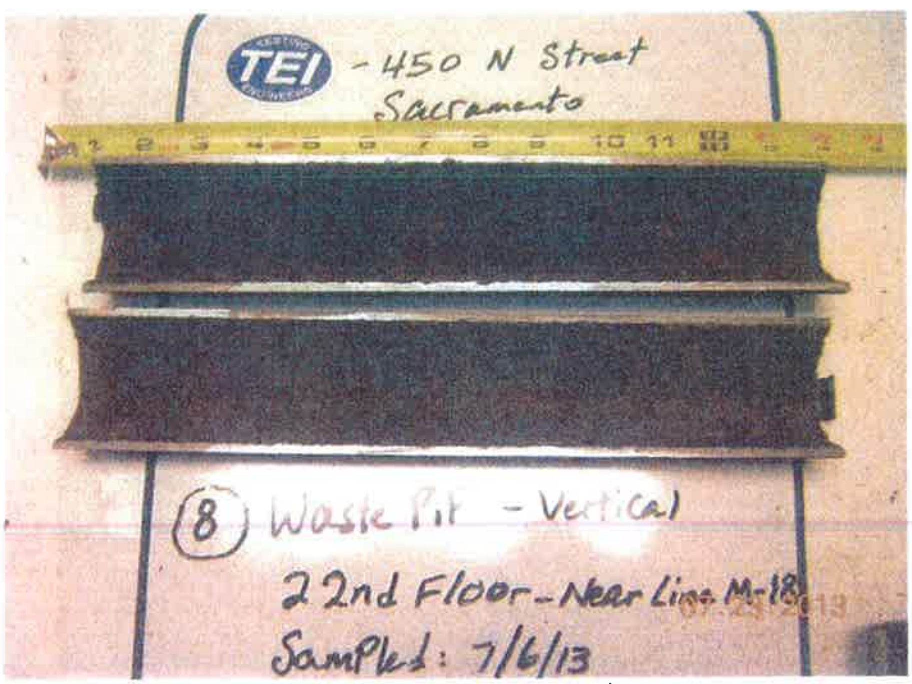


Photo 24 – Sample 8 - Interior

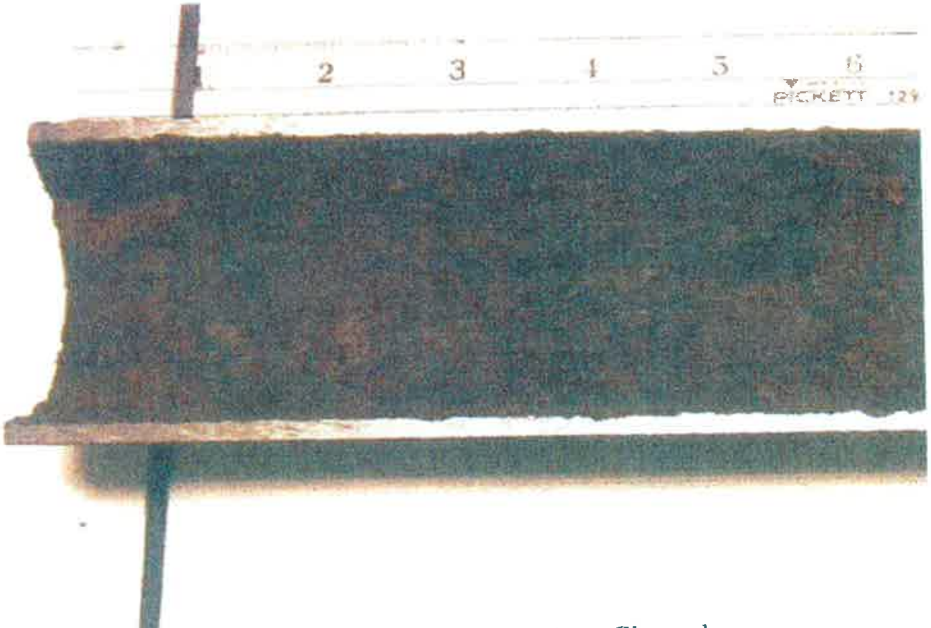


Photo 25 - Sample 8 - Interior - Cleaned

Photo 26 – Sample 9

Photo 27 – Sample 9 – Interior

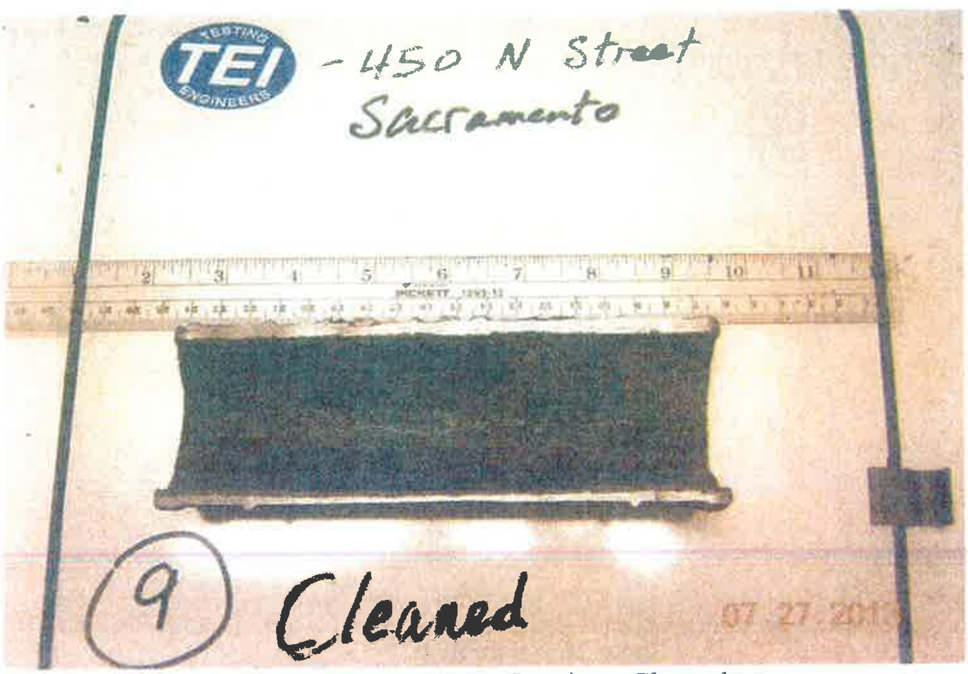


Photo 28 - Sample 9 - Interior – Cleaned

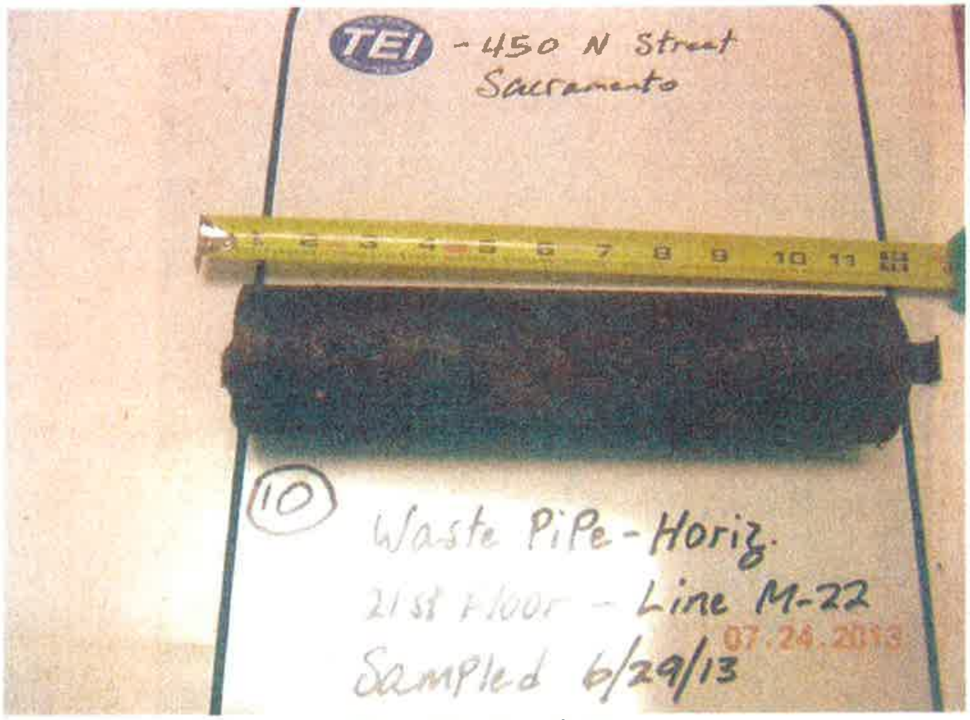


Photo 29 – Sample 10

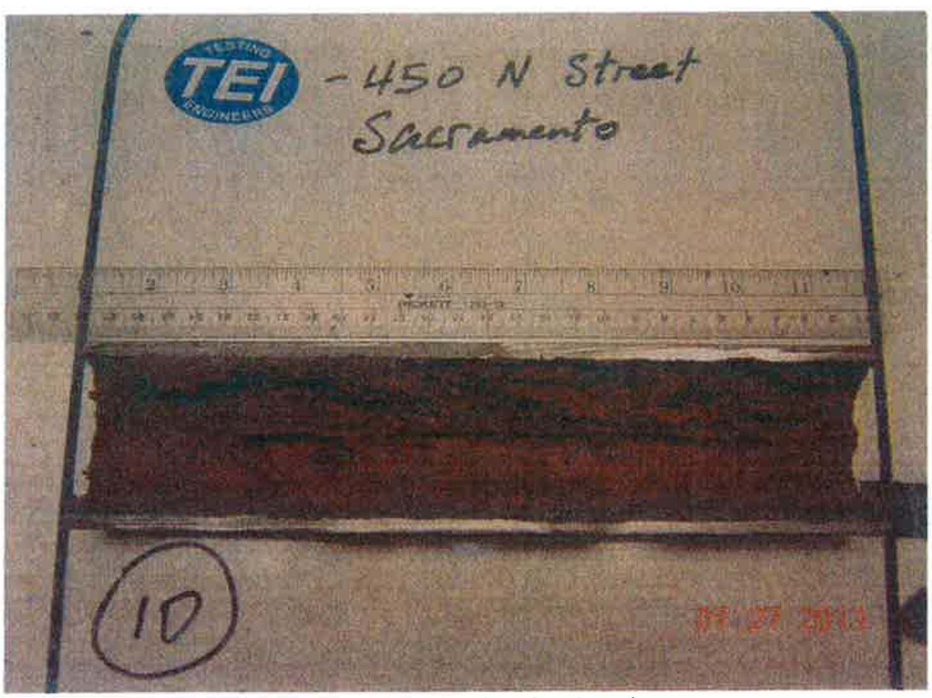


Photo 30 – Sample 10 – Interior

Photo 31 – Sample 10 - Interior – Cleaned

Photo 32 – Sample 11

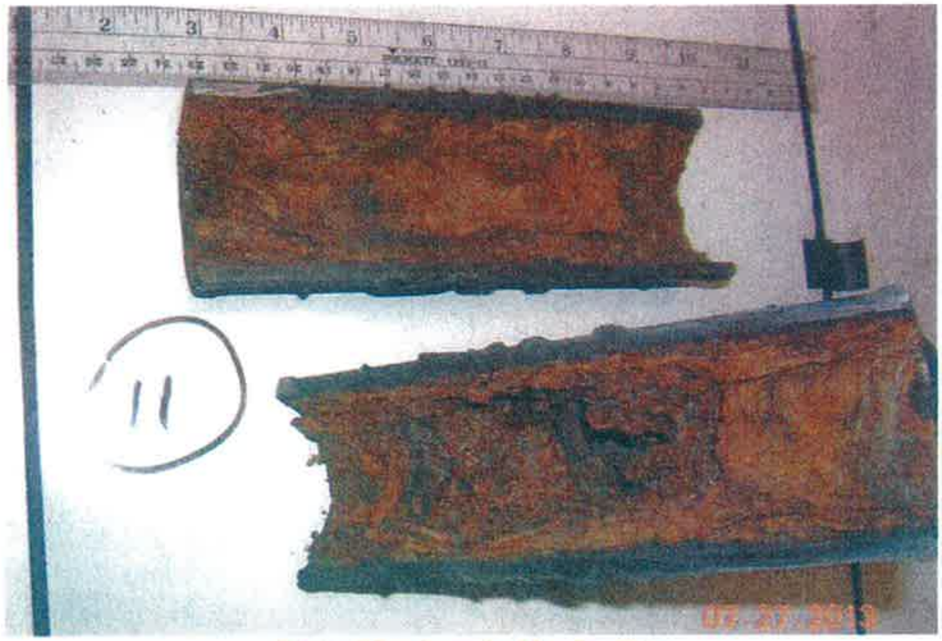


Photo 33 – Sample 11 – Interior

Photo 34 – Sample 11 - Interior – Cleaned

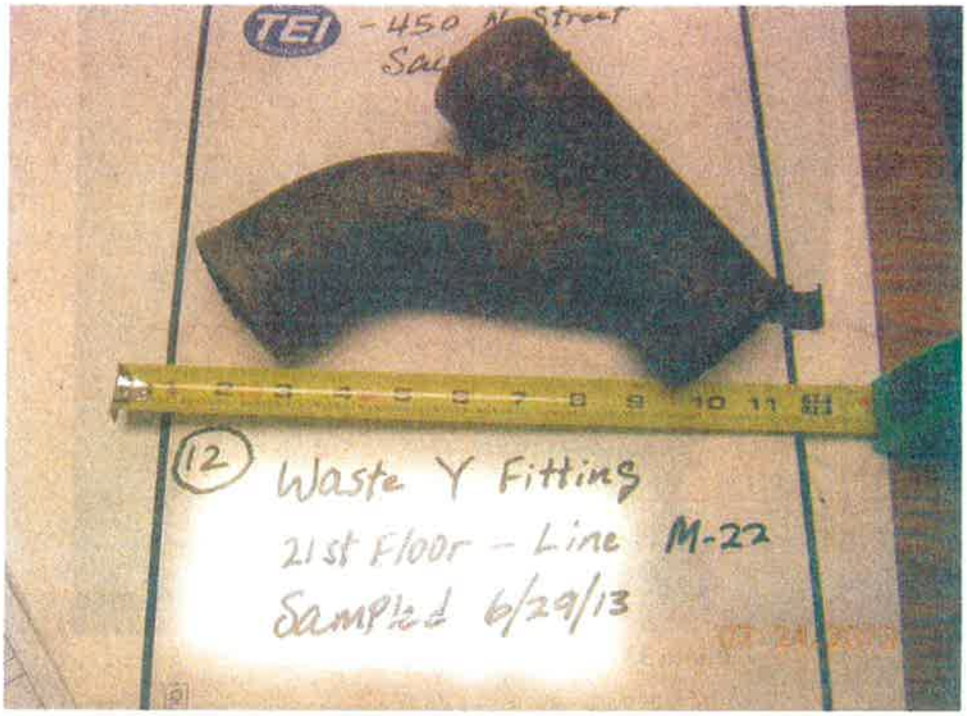


Photo 35 – Sample 12

Photo 36 – Sample 12 – Interior

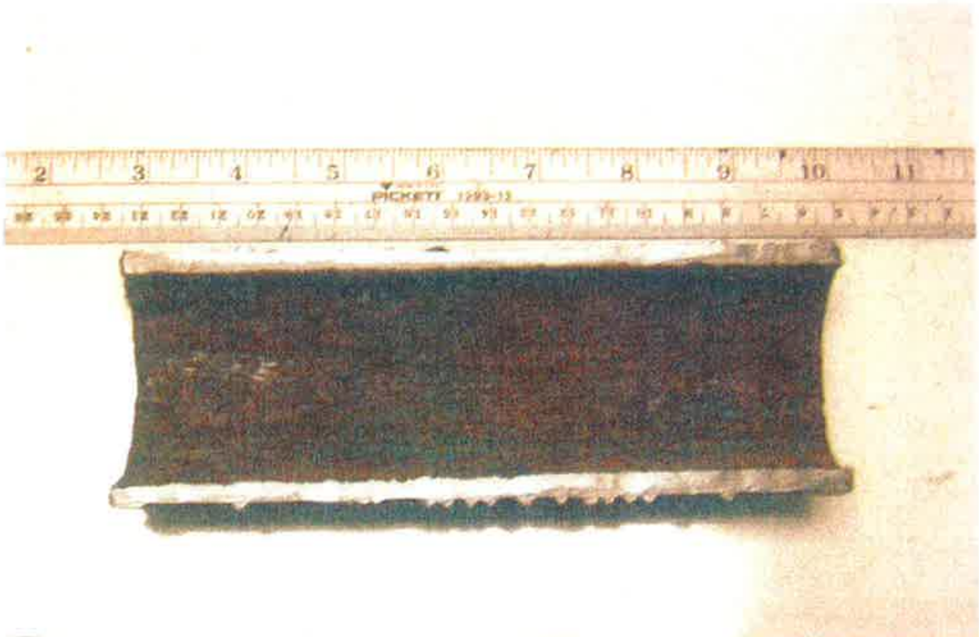


Photo 37 – Sample 12 - Interior – Cleaned

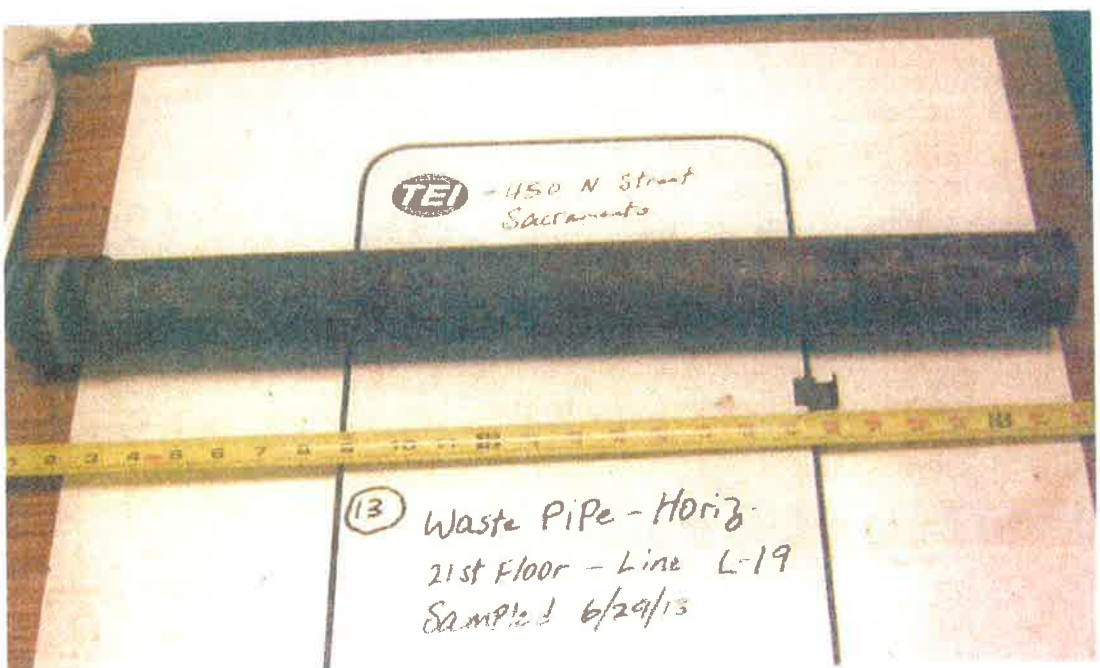


Photo 38 – Sample 13

Photo 39 – Sample 13 – Interior

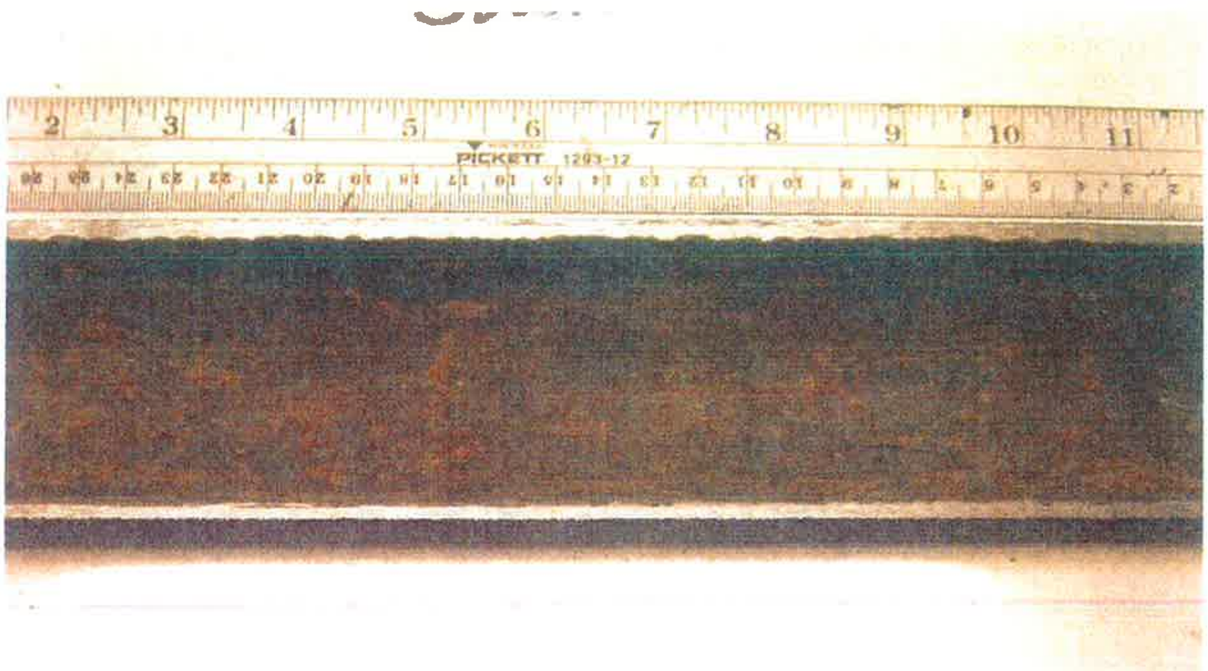


Photo 40 – Sample 13 - Interior – Cleaned

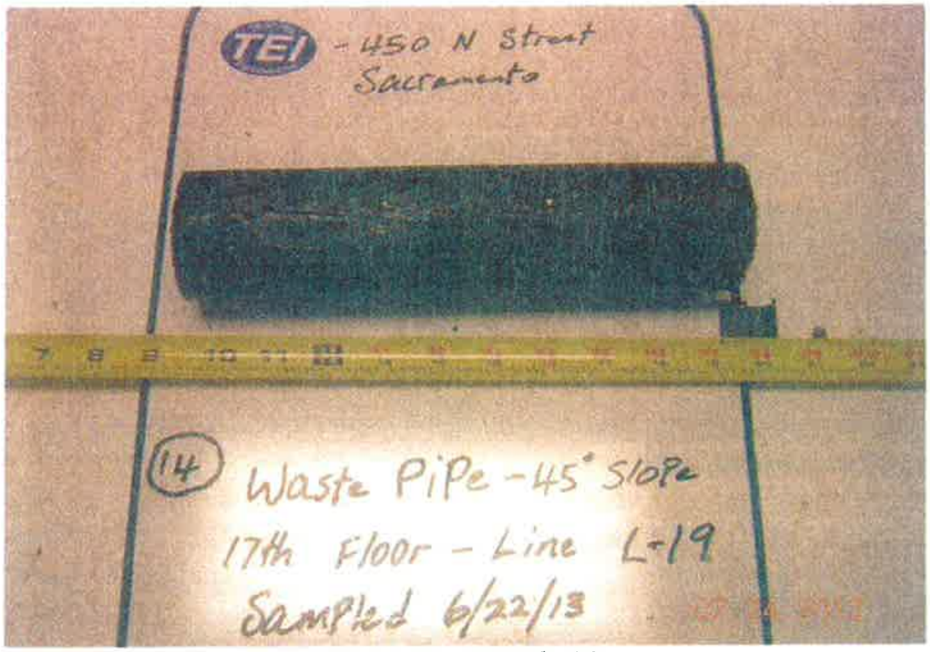


Photo 41 – Sample 14

Photo 42 – Sample 14 – Interior

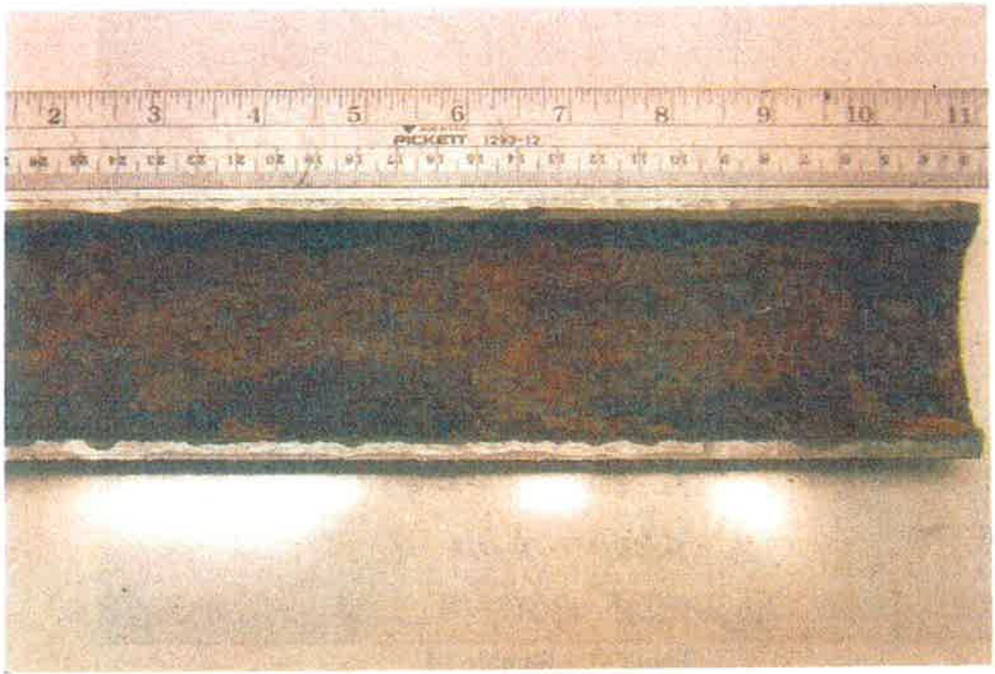


Photo 43 – Sample 14 - Interior – Cleaned

Photo 44 – Sample 15

Photo 45 – Sample 15 – Interior

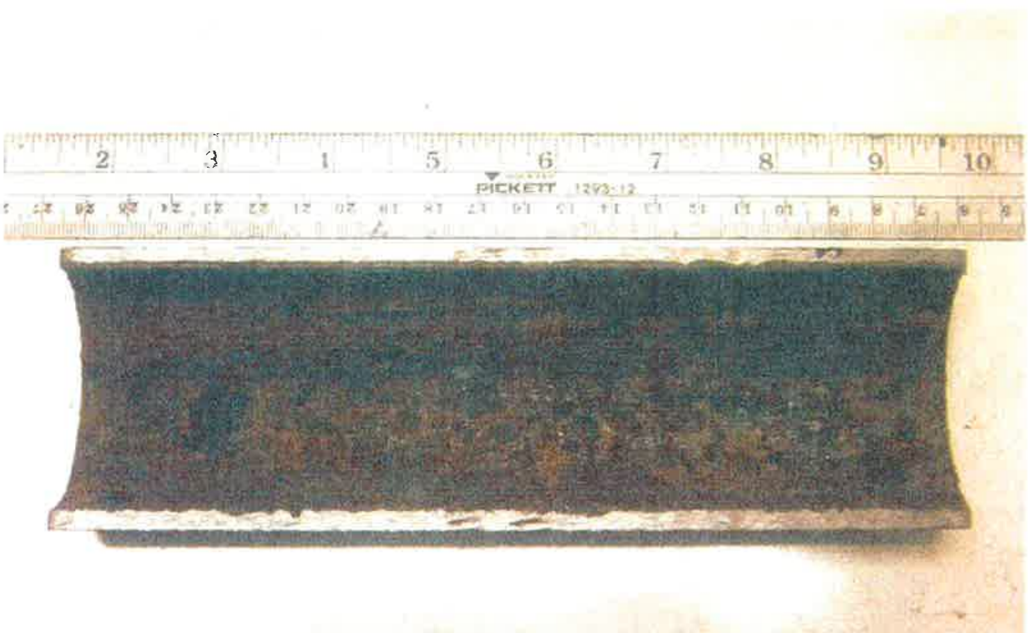


Photo 46 – Sample 15 - Interior – Cleaned

Photo 47 – Sample 16 & 17 (same section)

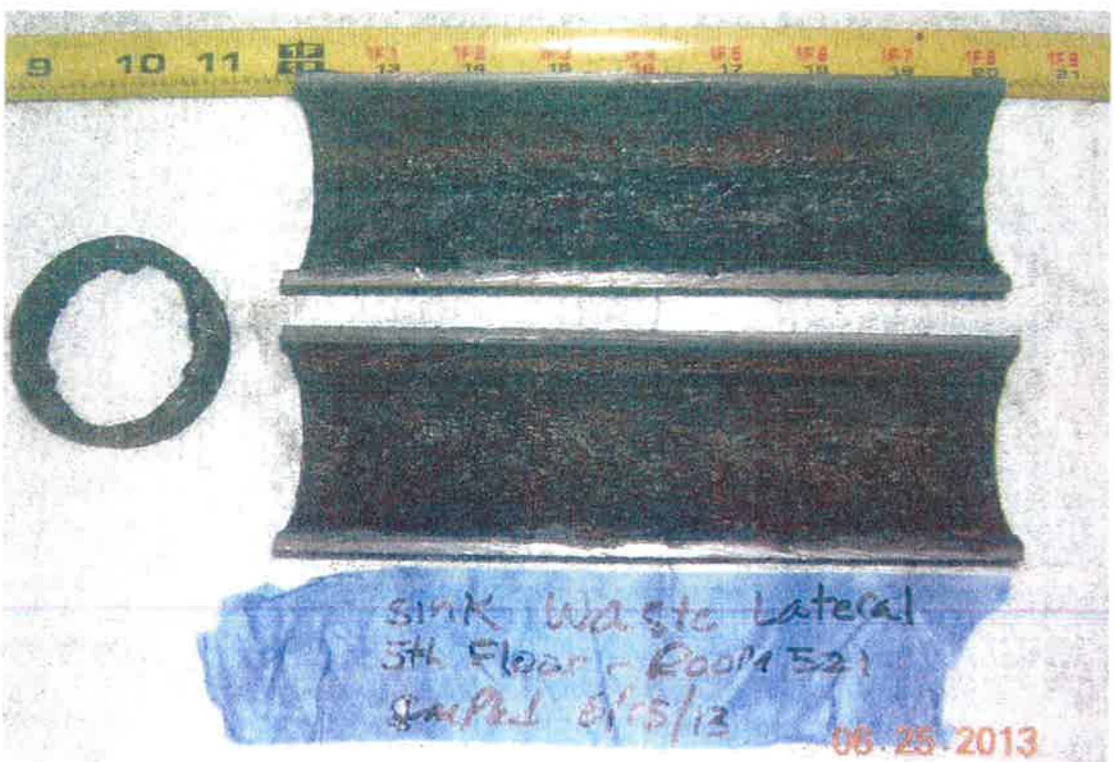


Photo 48 – Sample 16 - Interior

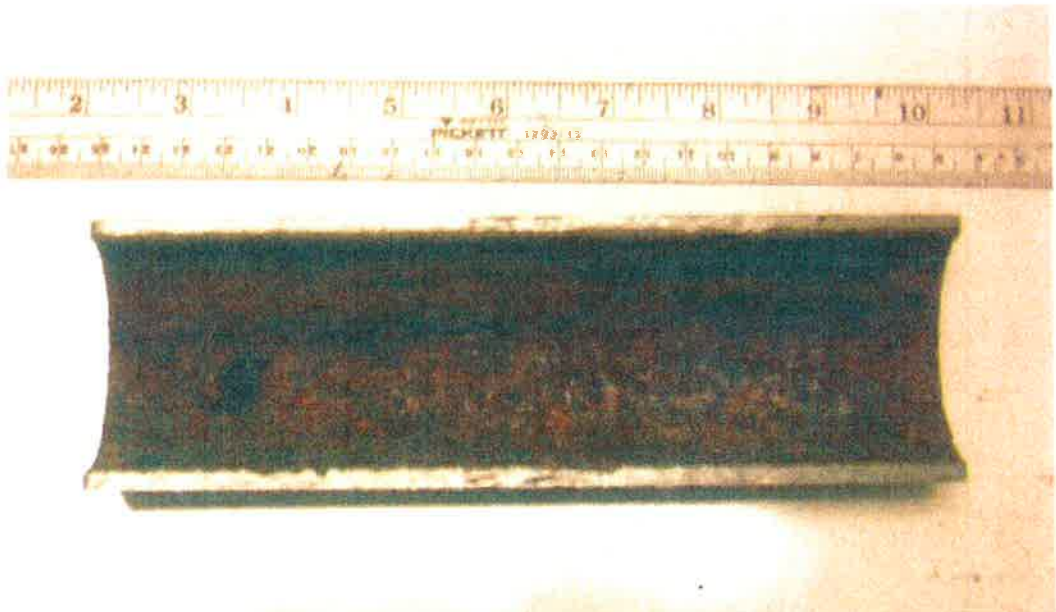


Photo 49 – Sample 16 - Interior – Cleaned

Photo 50 – Sample 18

Photo 51 – Sample 18 – Interior

Photo 52 – Sample 18 - Interior – Cleaned

Photo 53 – Sample 19

Photo 54 – Sample 19 – Interior

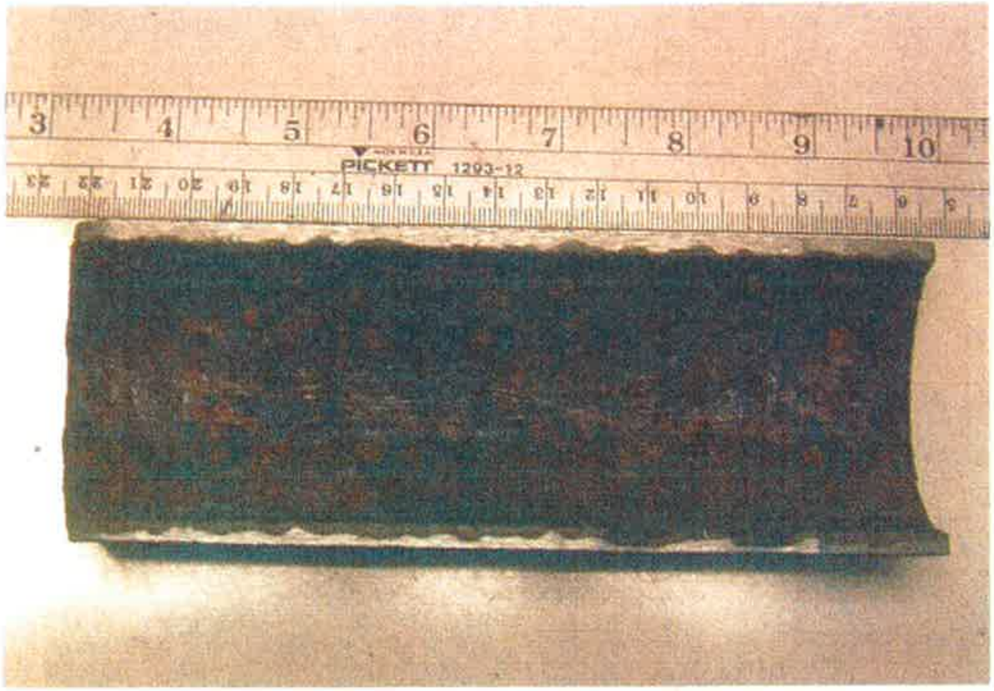


Photo 55 – Sample 19 - Interior – Cleaned

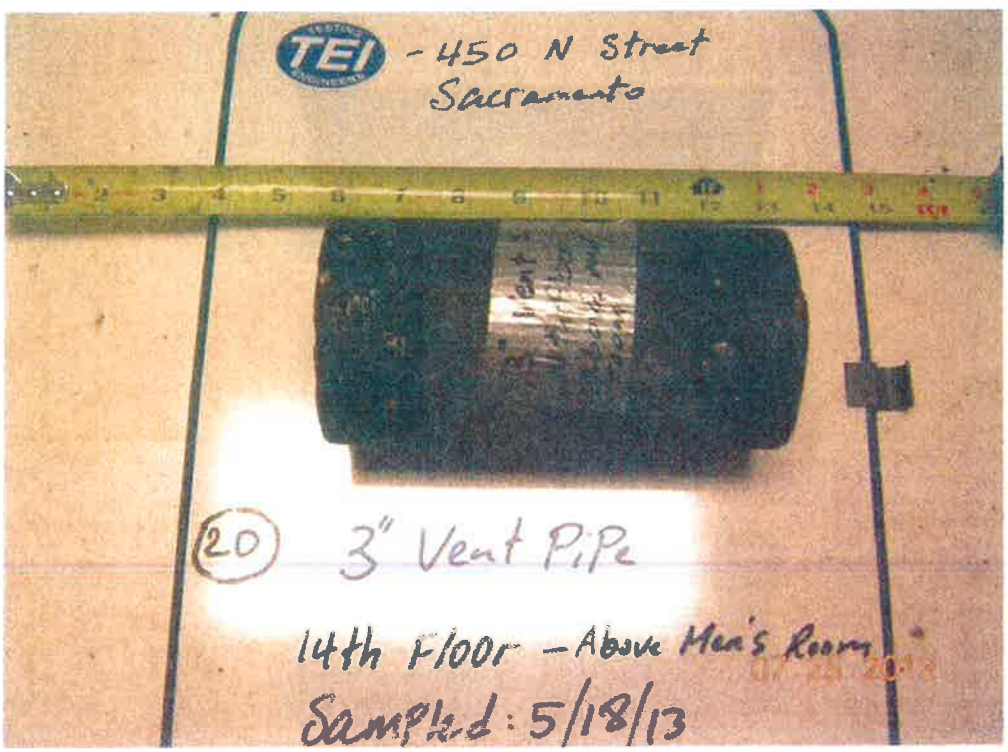


Photo 56 – Sample 20

Photo 57 – Sample 20 – Interior View

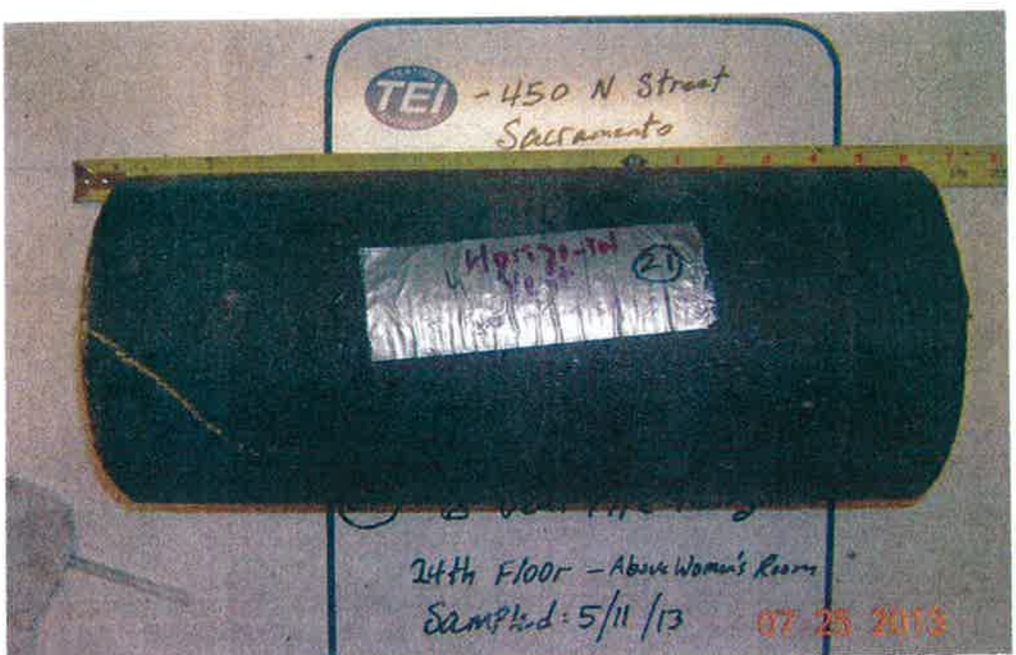


Photo 58 – Sample 21

Photo 59– Sample 21 – Interior View

Photo 60 – Sample 22

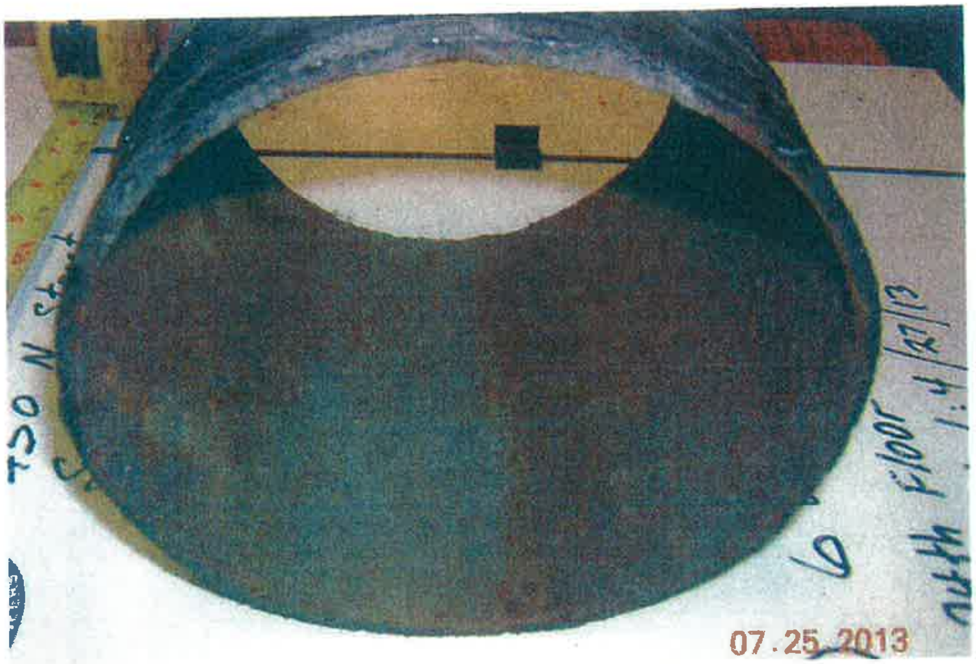


Photo 61– Sample 22 – Interior View

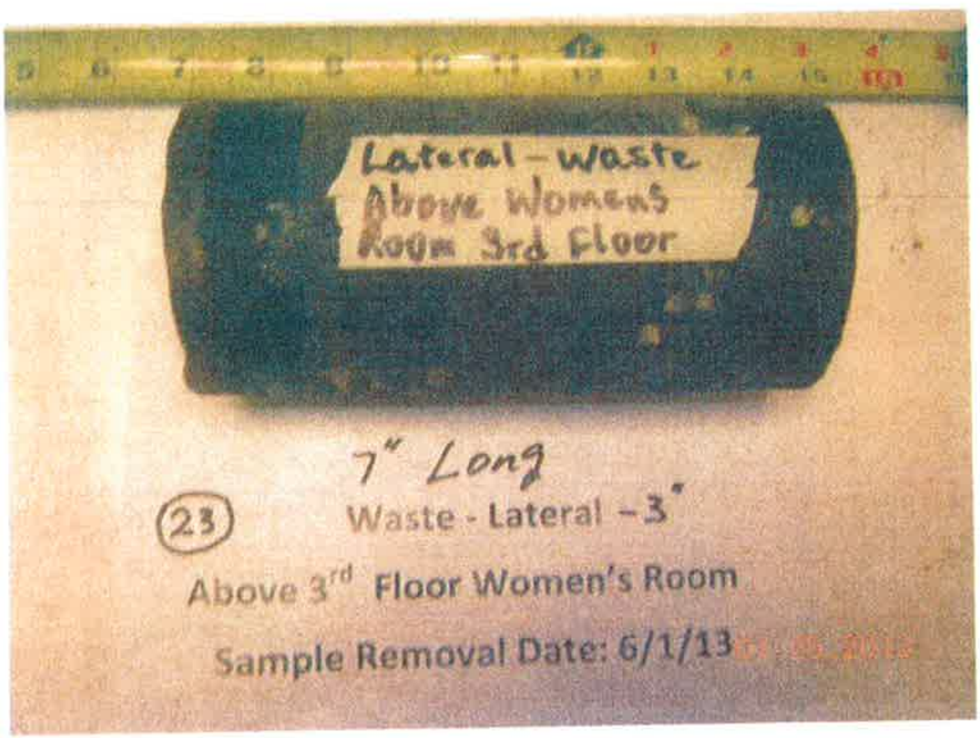


Photo 62 – Sample 23

Photo 63 – Sample 23 - Interior View

Photo 64 - Sample 2 - Cross Section

Photo 65 - Sample 4 - Cross Section

Photo 66 - Sample 4 - Cross Section

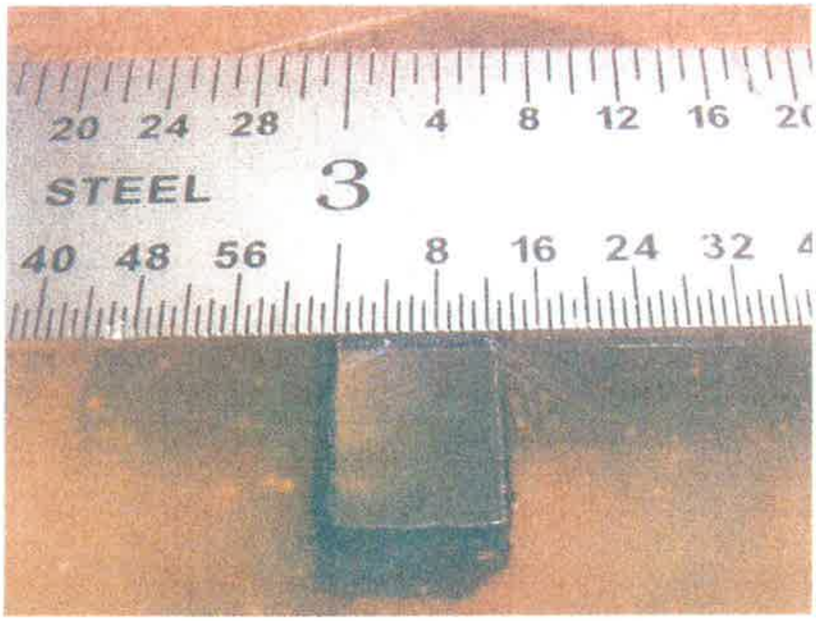


Photo 67 - Sample 5 - Cross Section

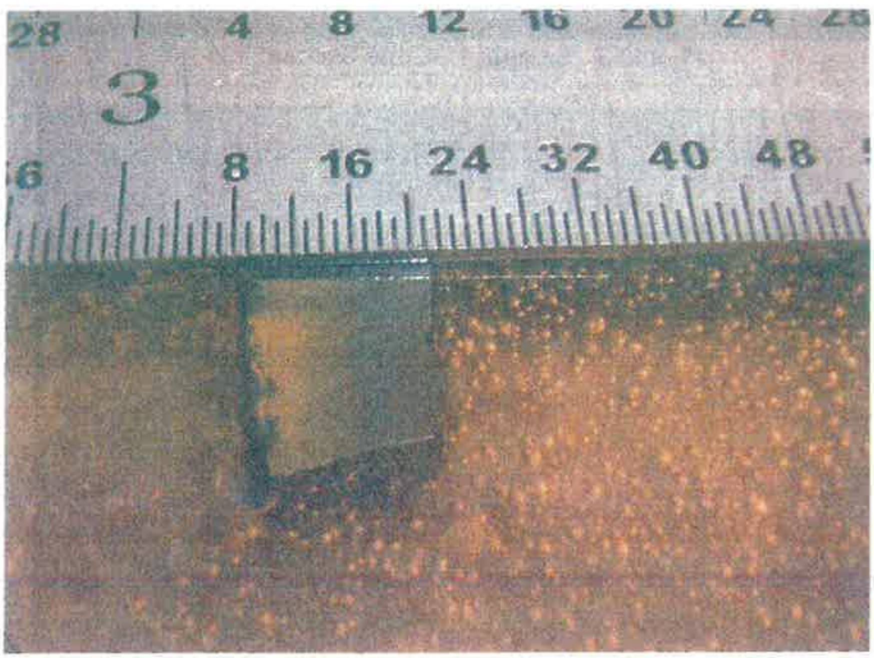


Photo 68 - Sample 6 - Cross Section

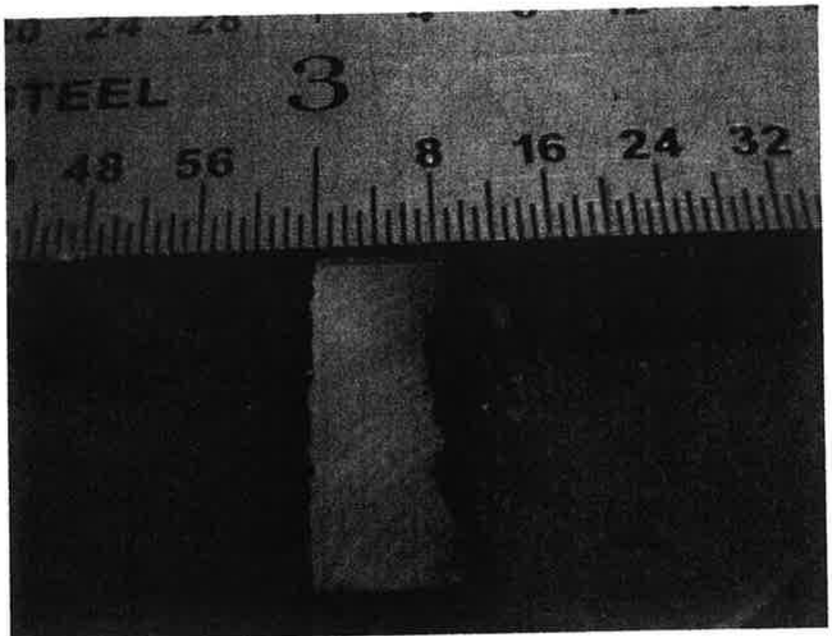


Photo 69 - Sample 8 - Cross Section

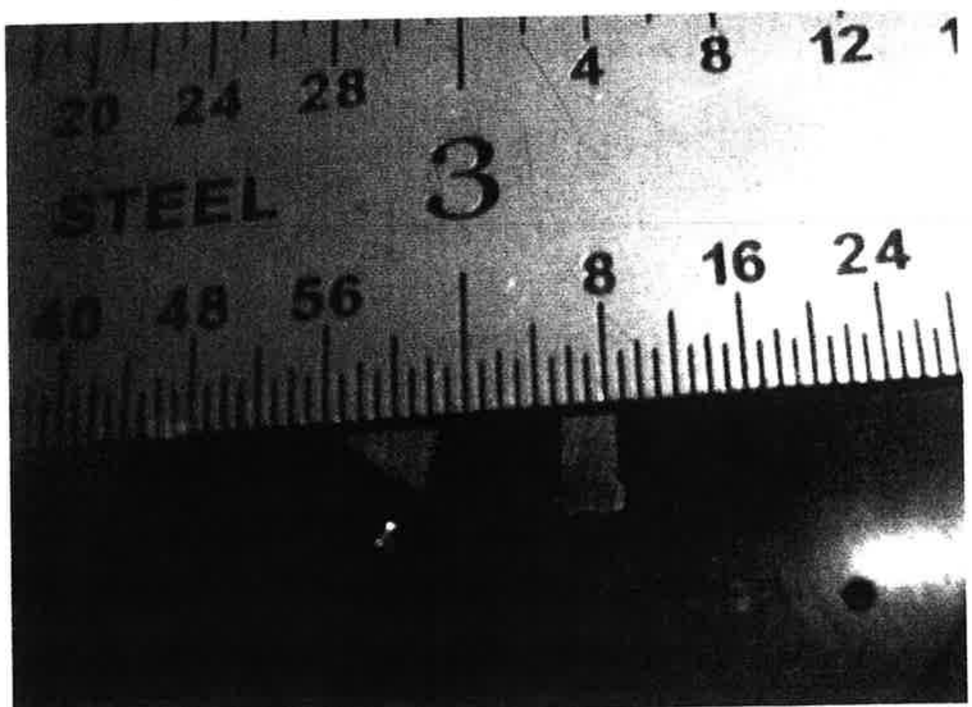


Photo 70 - Sample 9 - Cross Section

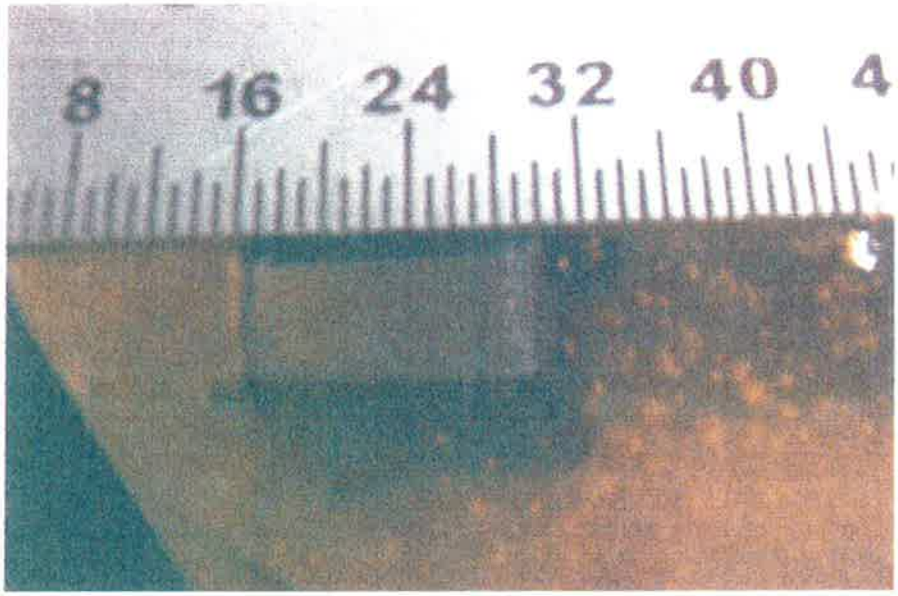


Photo 71 - Sample 9 - Cross Section

Photo 72 - Sample 12 - Cross Section

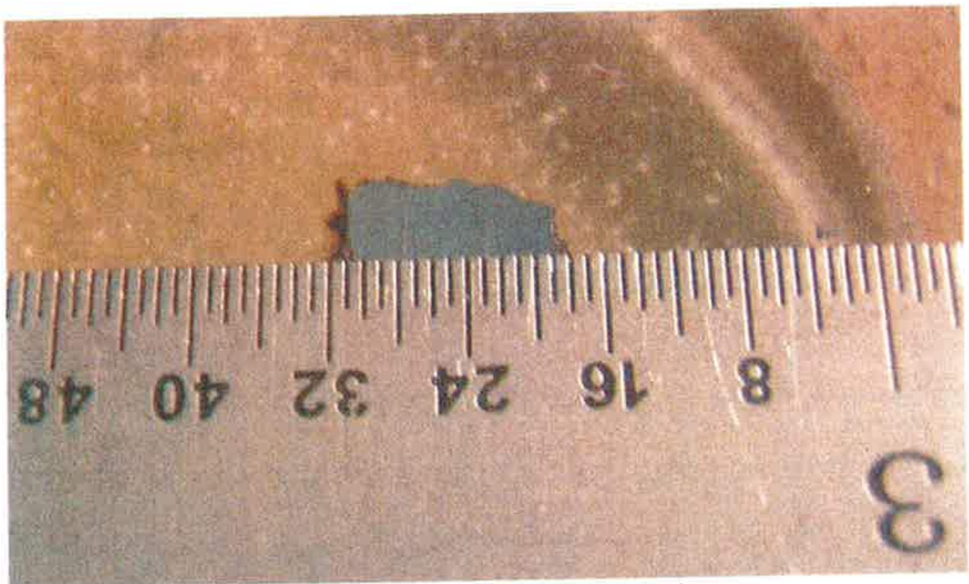


Photo 73 - Sample 12 - Cross Section

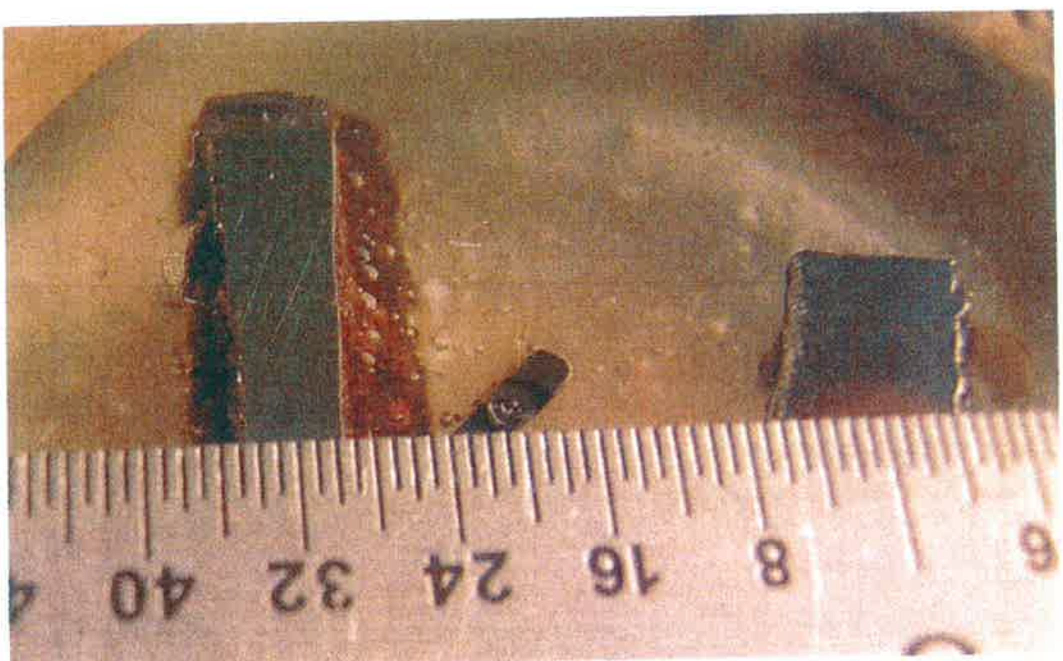


Photo 74 – Sample 15 - Cross Section

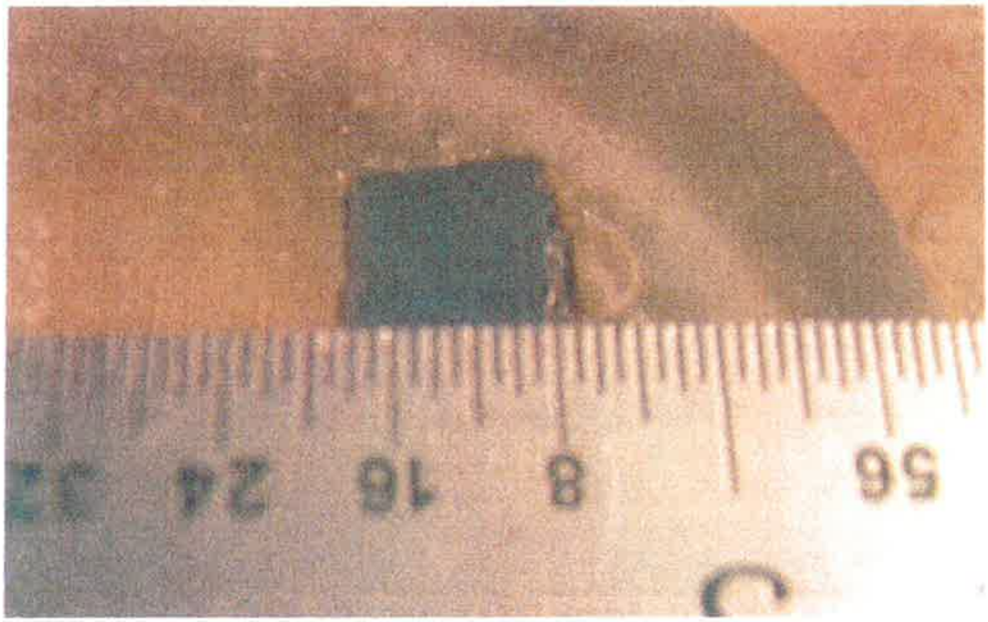


Photo 75 – Sample 15 - Cross Section

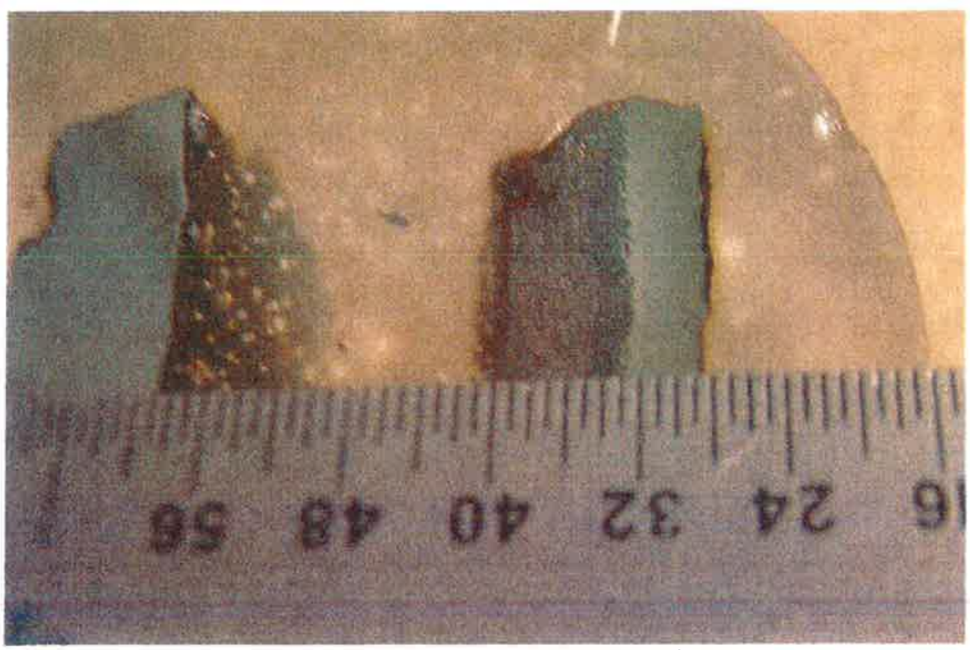


Photo 76 – Sample 16 - Cross Section

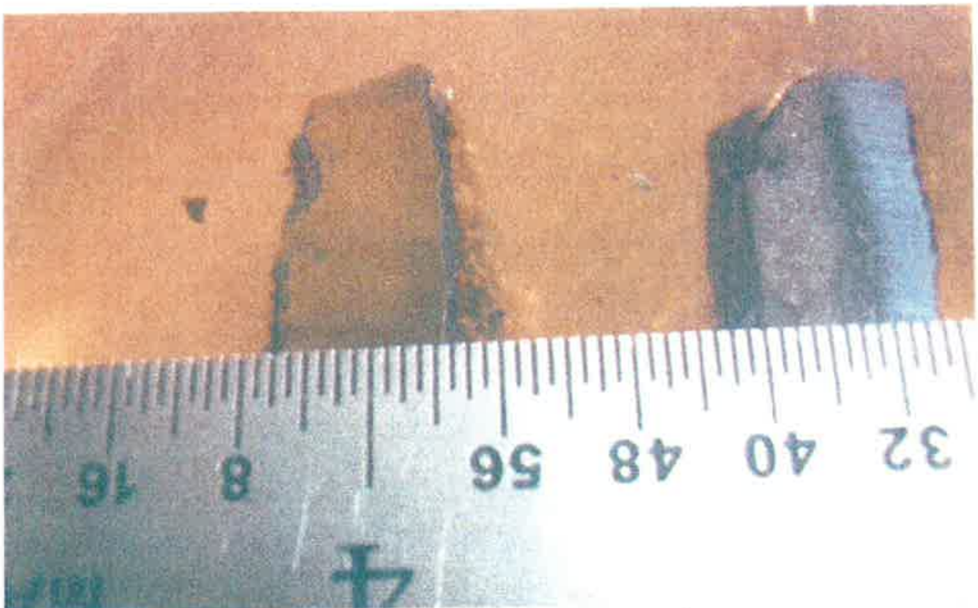


Photo 77 – Sample 16 - Cross Section

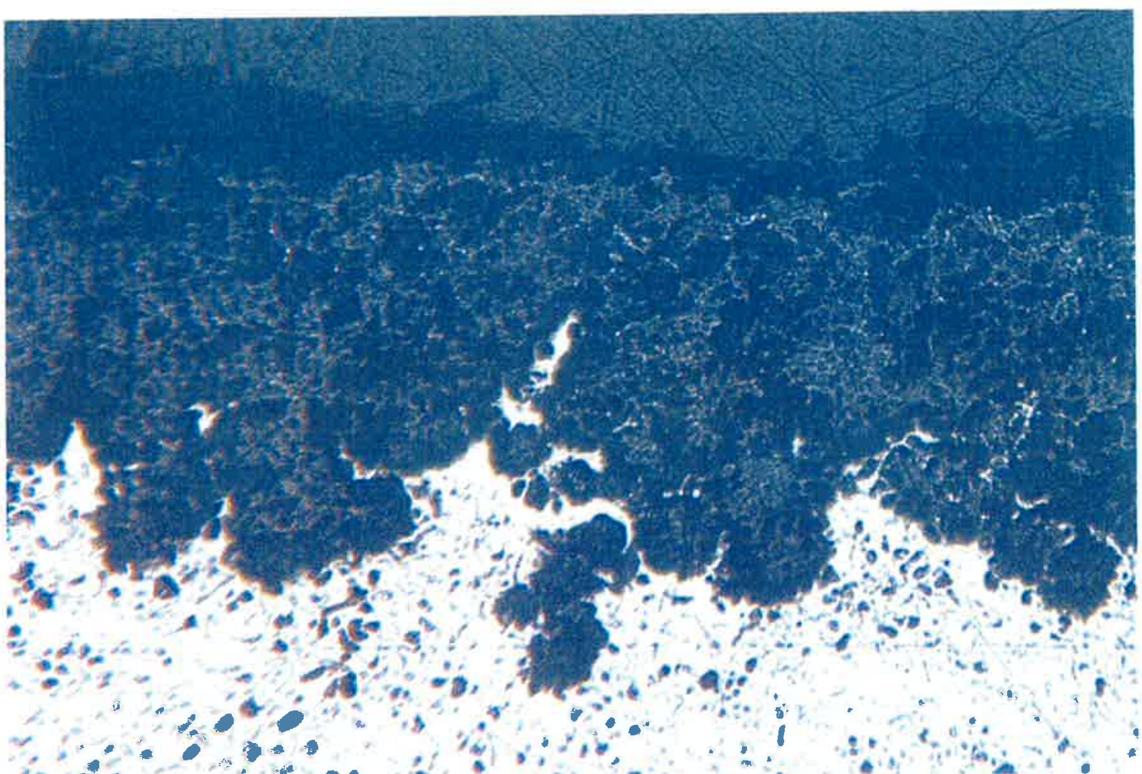


Photo 78 - Sample 2 – Cross Section Micrograph – Graphitized Area – 100X

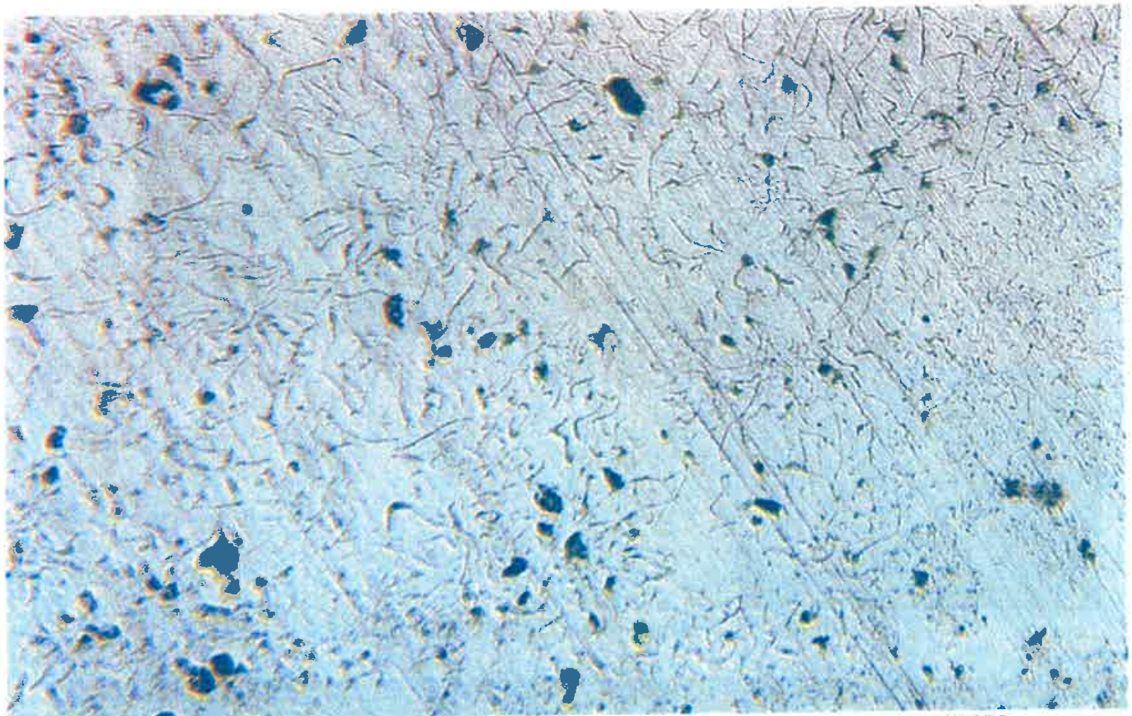


Photo 79 - Sample 2 – Cross Section Micrograph – Base Material - 100X

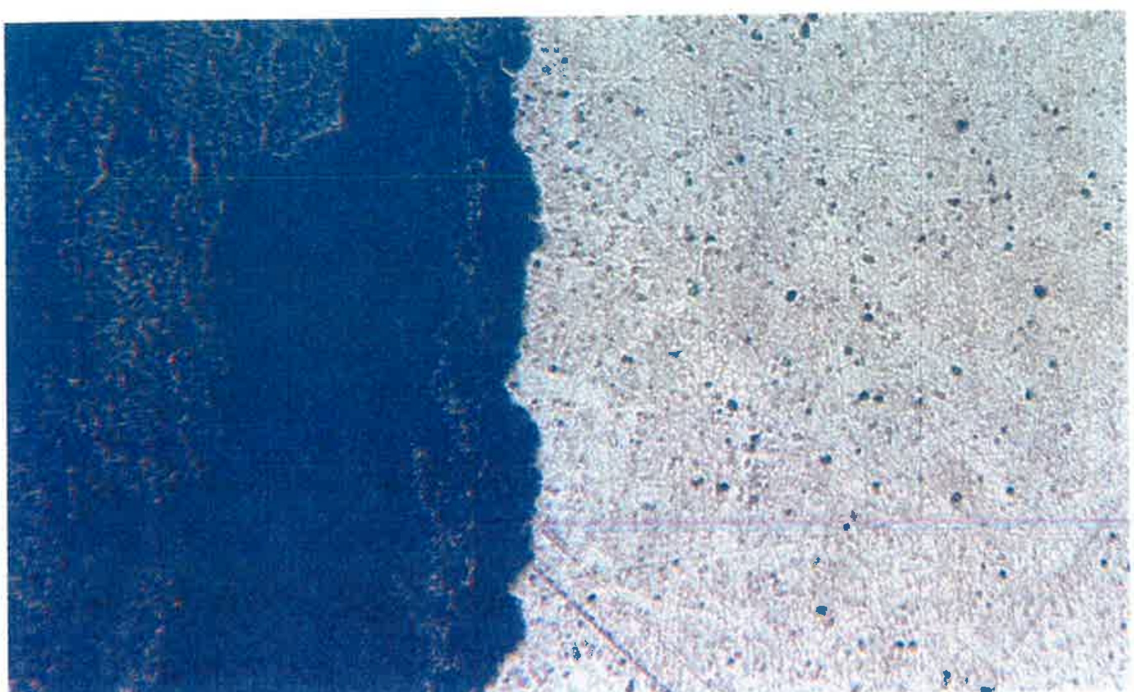


Photo 80 - Sample 4 – Cross Section Micrograph – Pitted Area – 100X

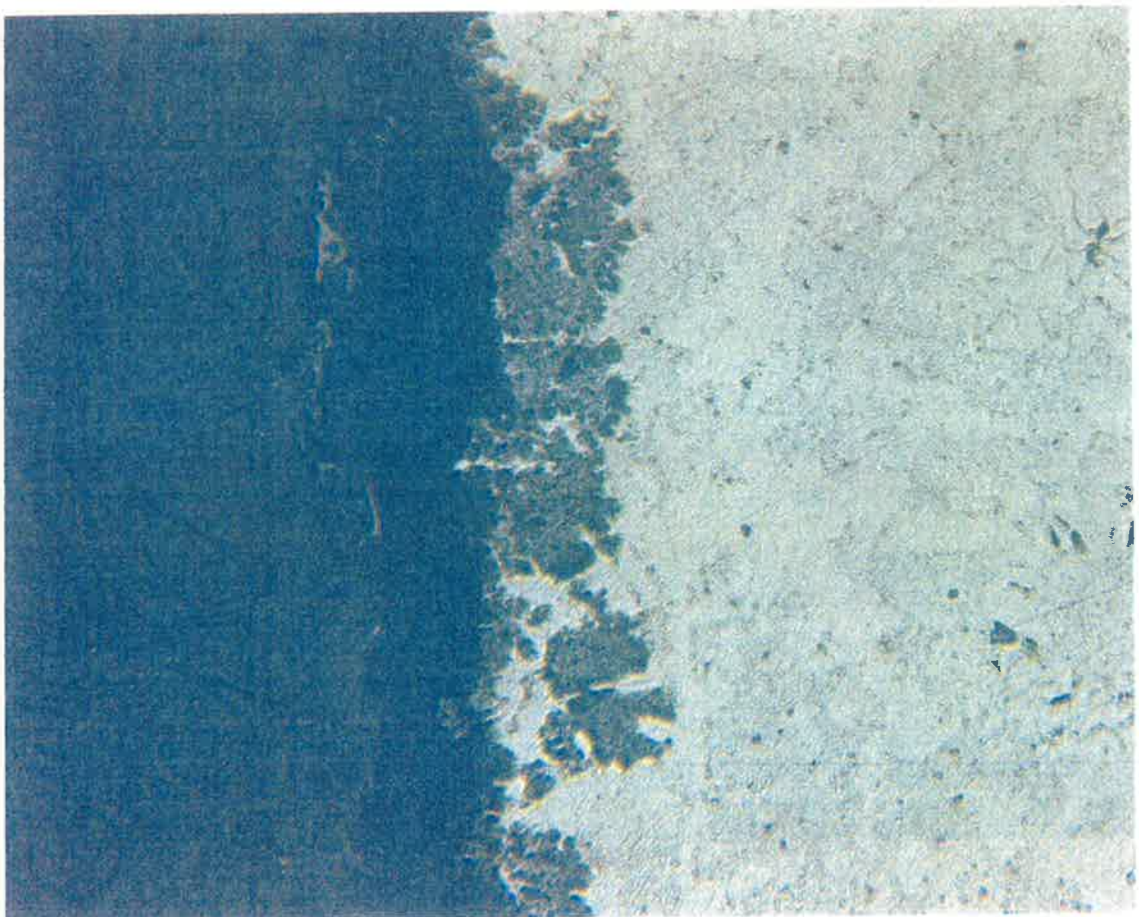


Photo 81 - Sample 5 -- Cross Section Micrograph – Graphitized Area – 100X

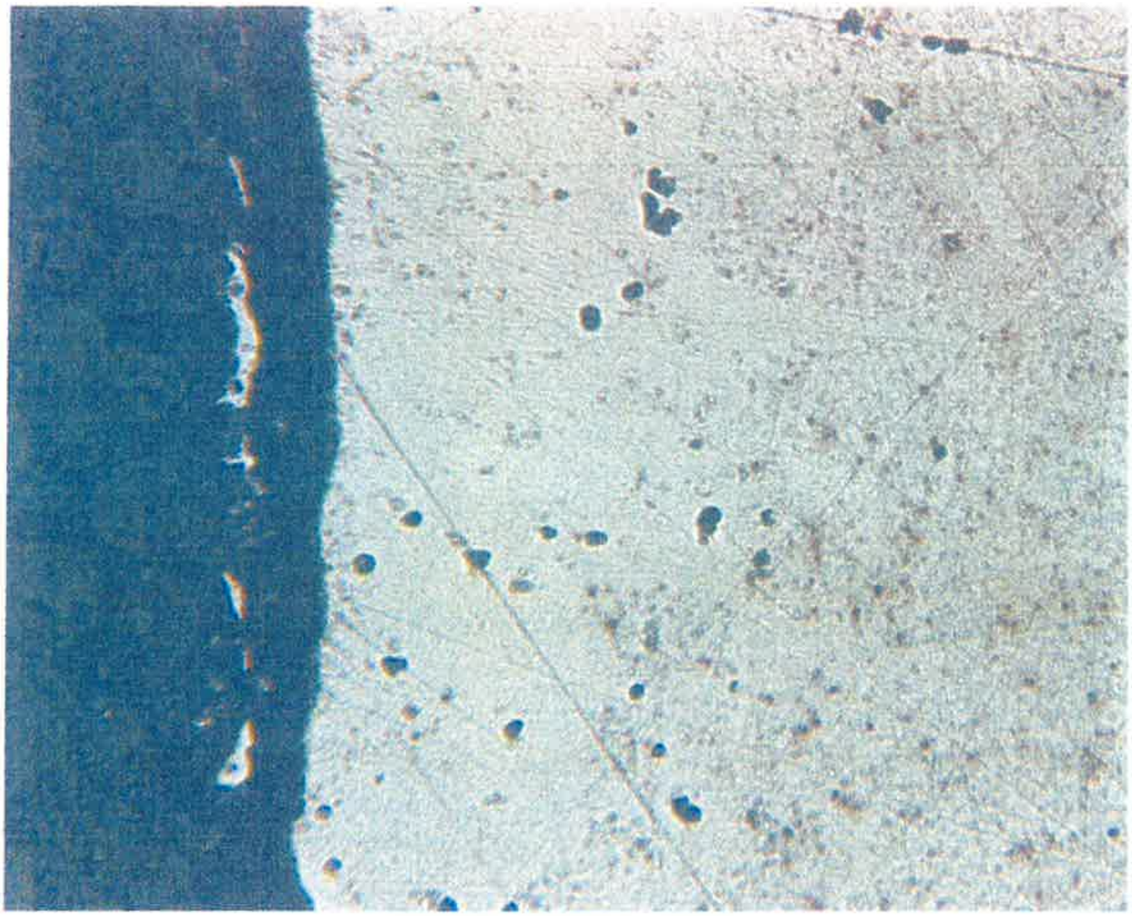


Photo 82 - Sample 6 – 100X

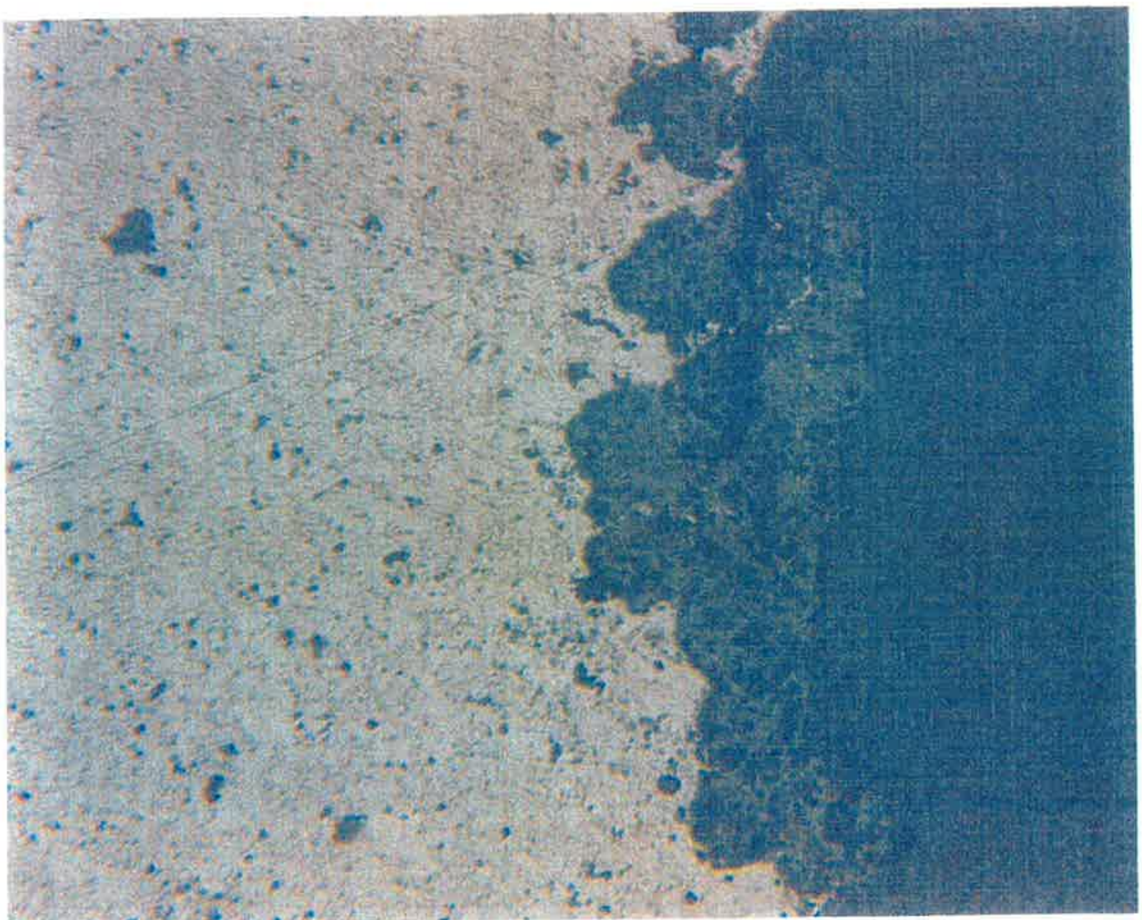


Photo 83 - Sample 8 – 100X

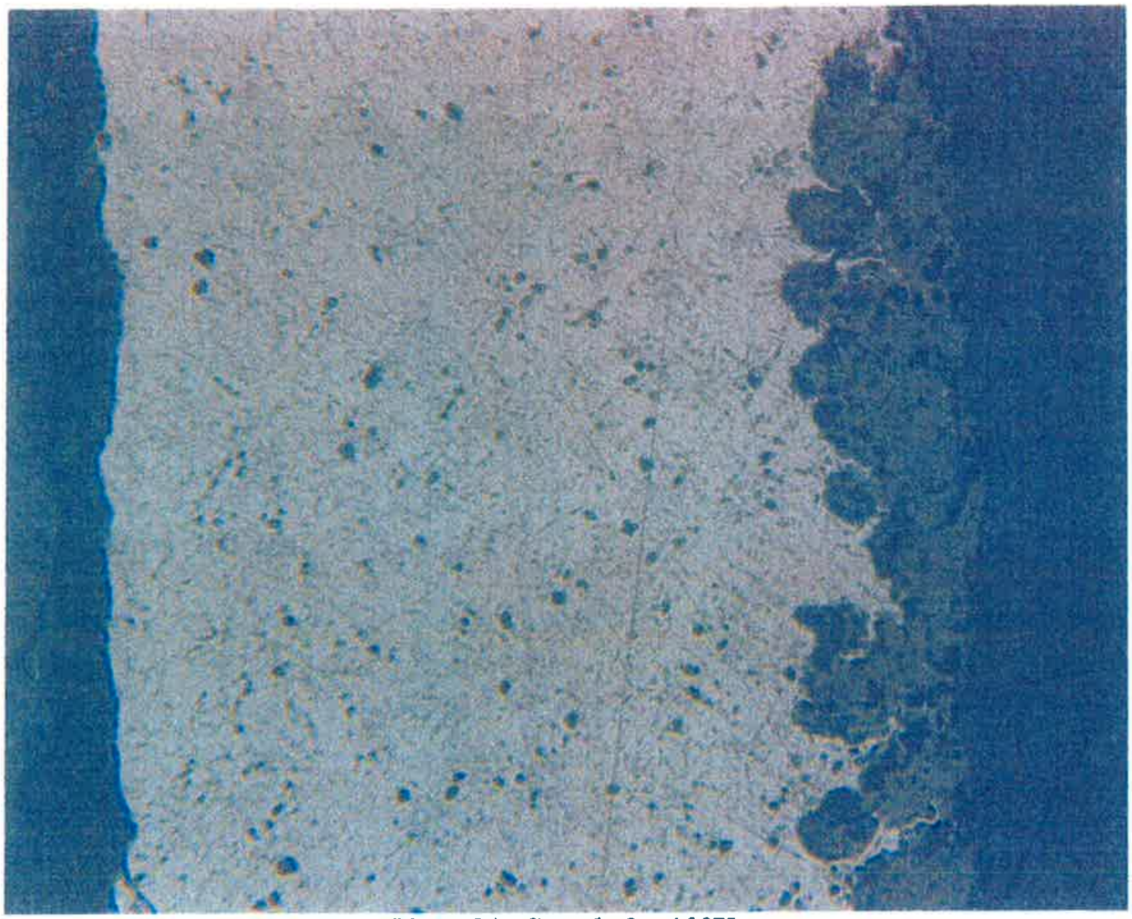


Photo 84 - Sample 9 – 100X

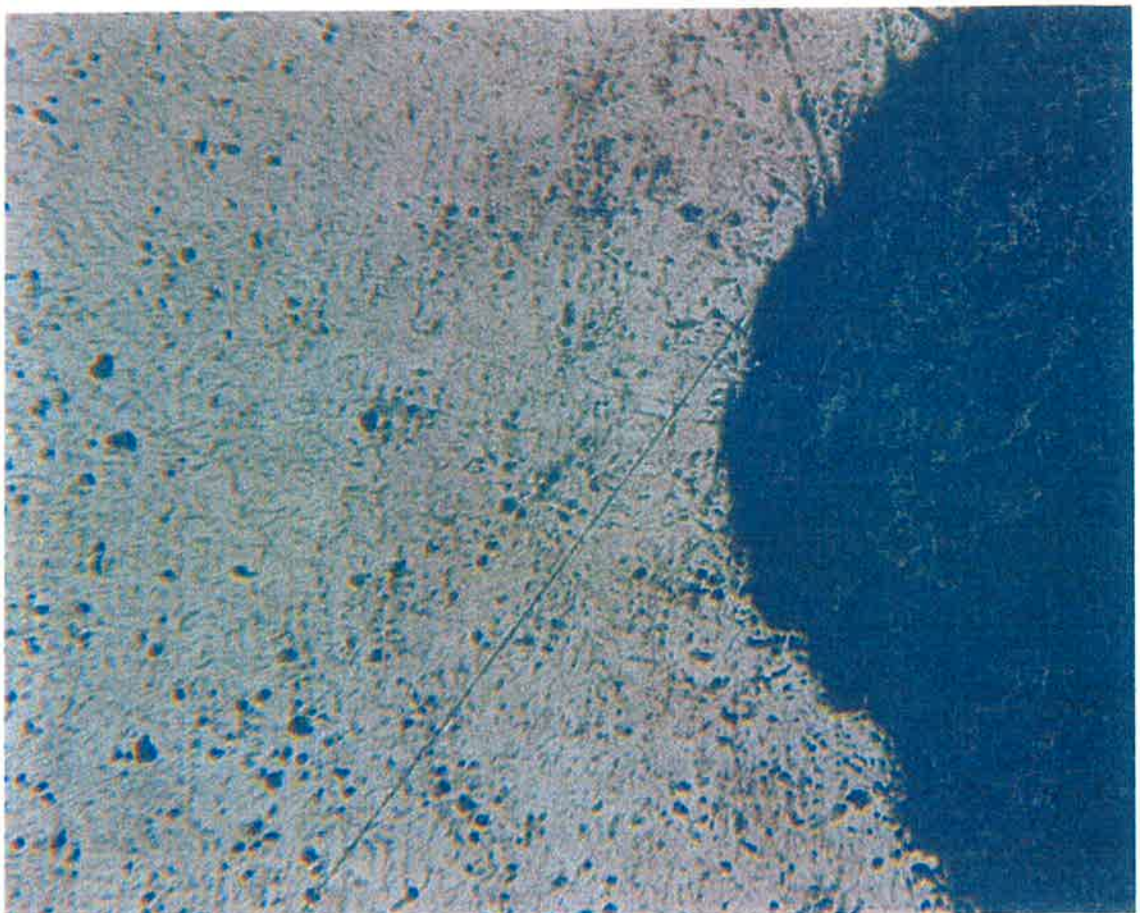


Photo 85 - Sample 12 – 100X

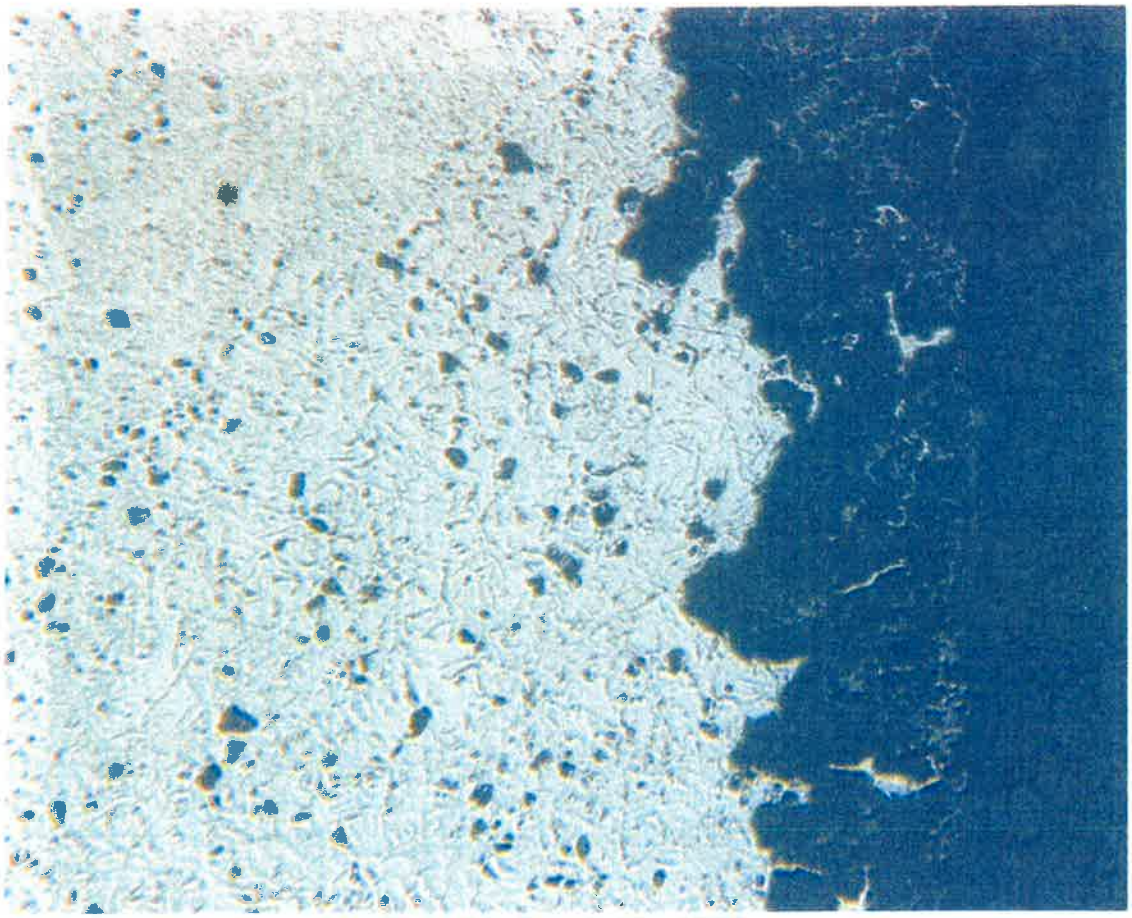


Photo 86 - Sample 15 – 100X

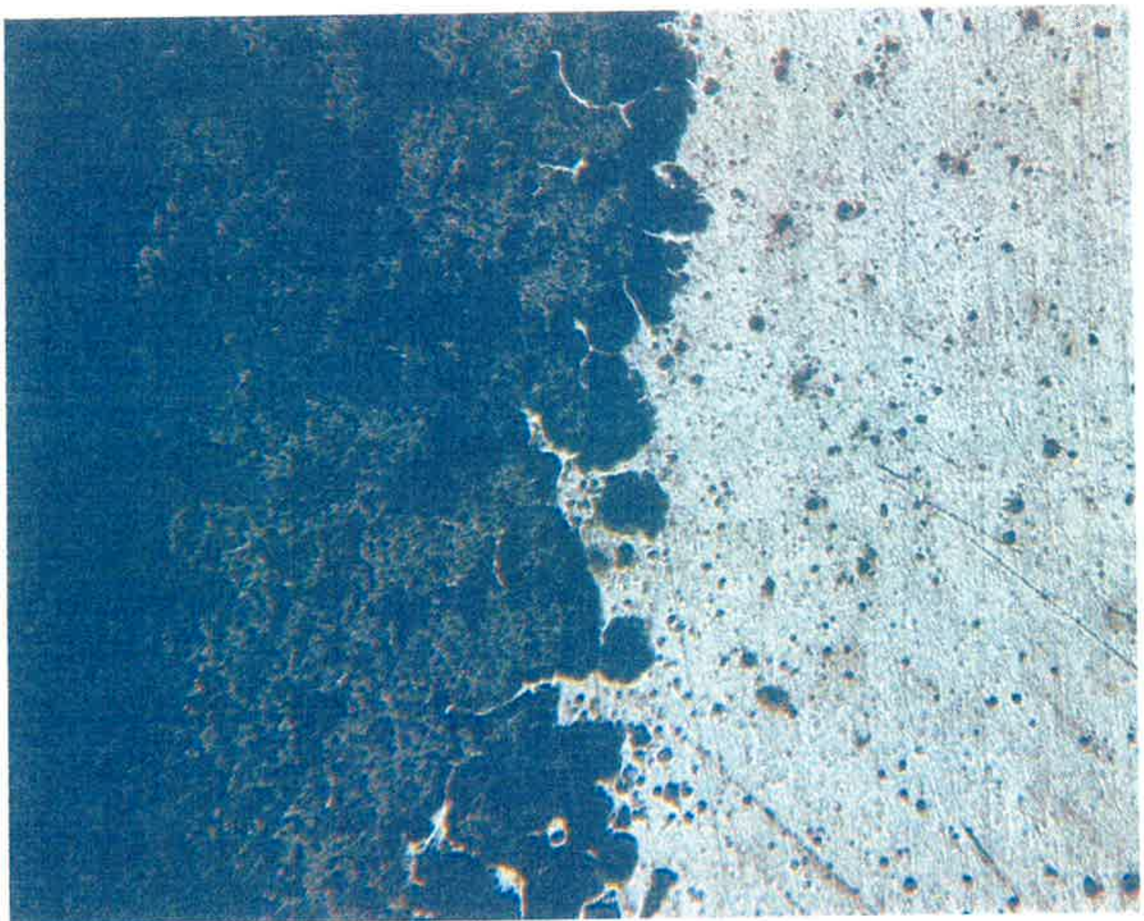


Photo 87 - Sample 16 – 100X

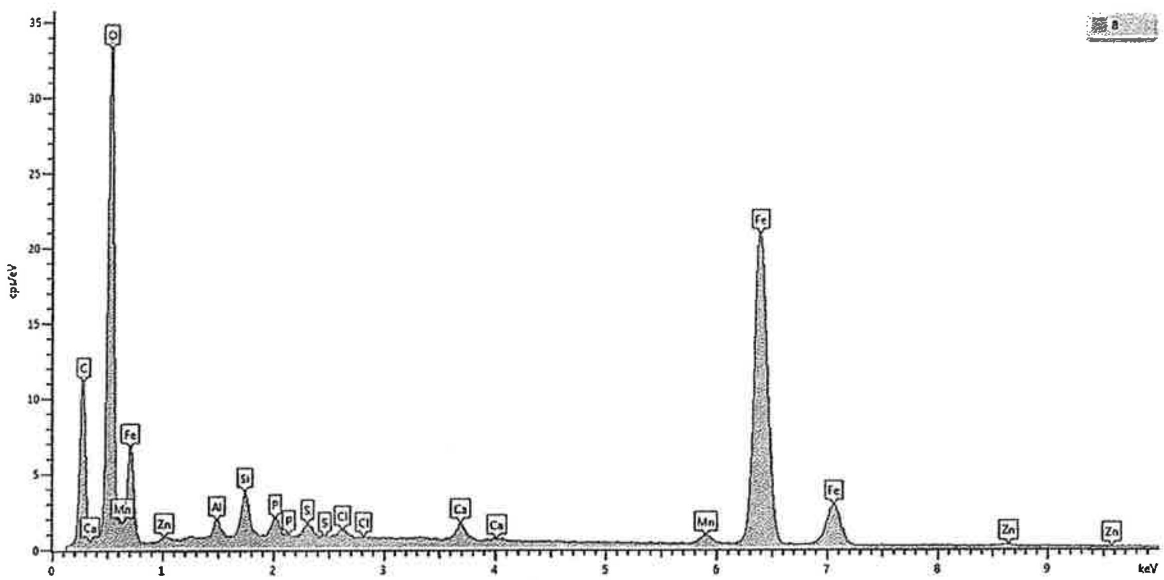


Figure 9
Analysis of Deposits from Pipe Sample 8

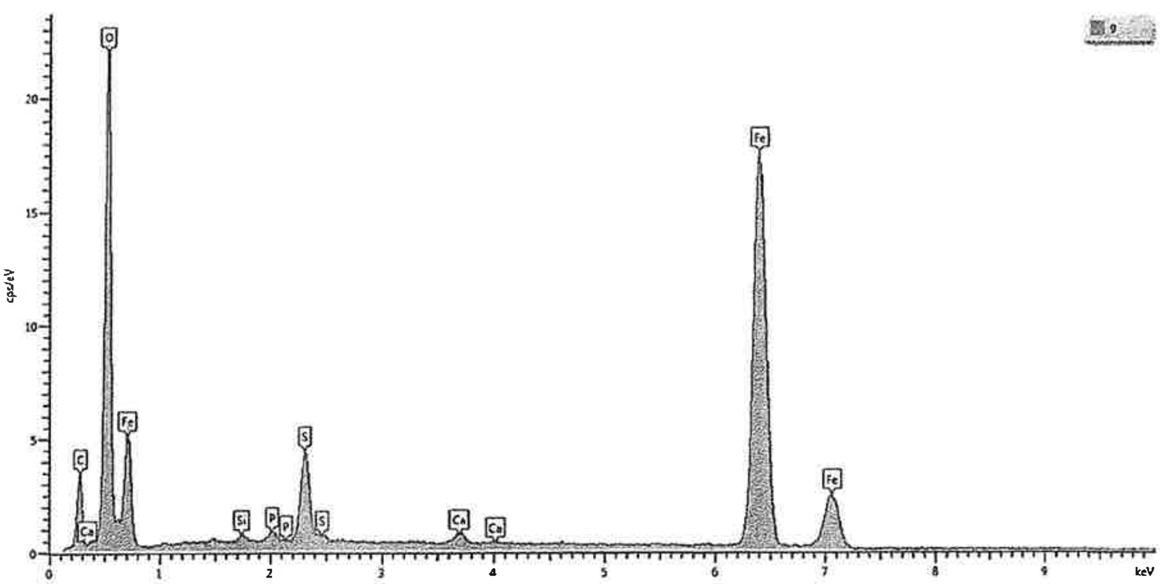


Figure 10
Analysis of Deposits from Pipe Sample 9

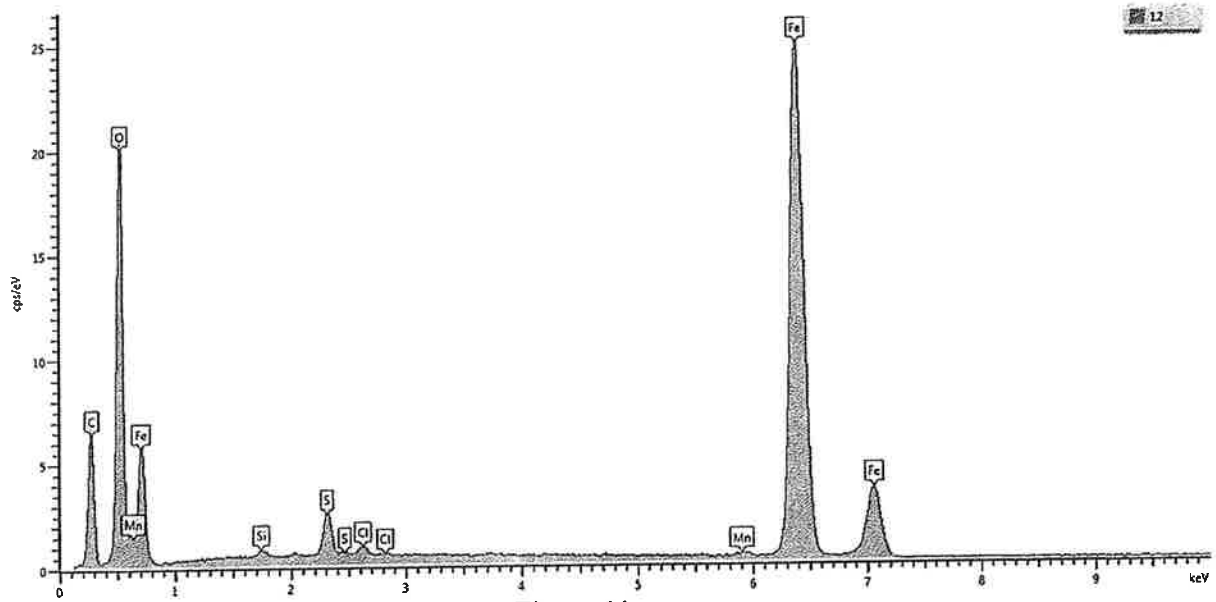


Figure 11
Analysis of Deposits from Pipe Sample 12

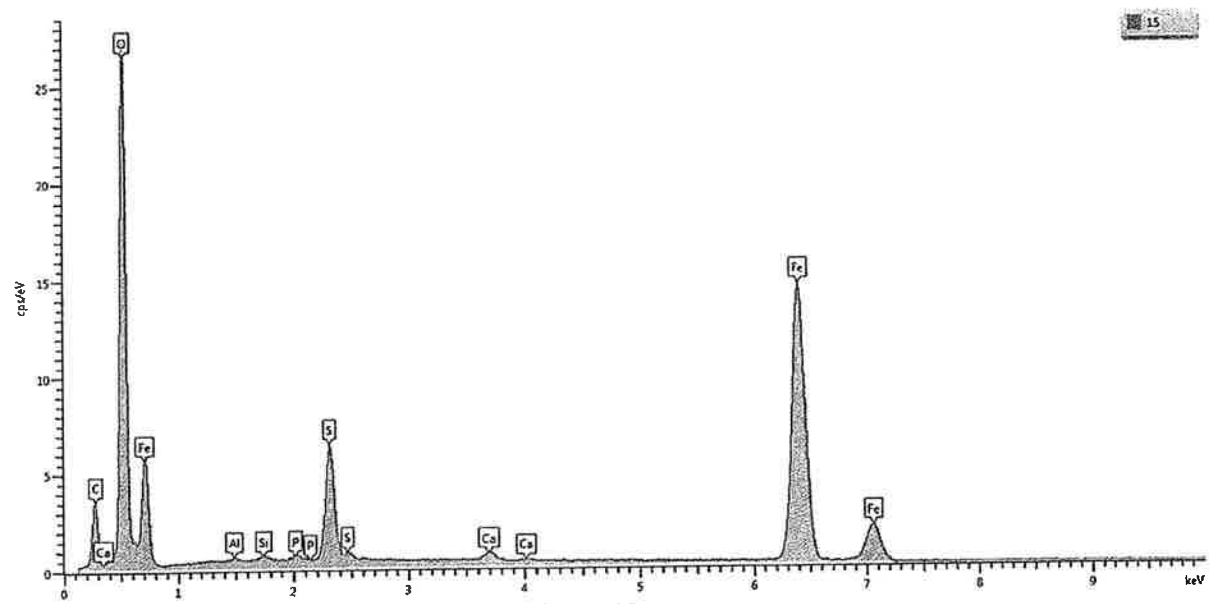


Figure 12
Analysis of Deposits from Pipe Sample 15

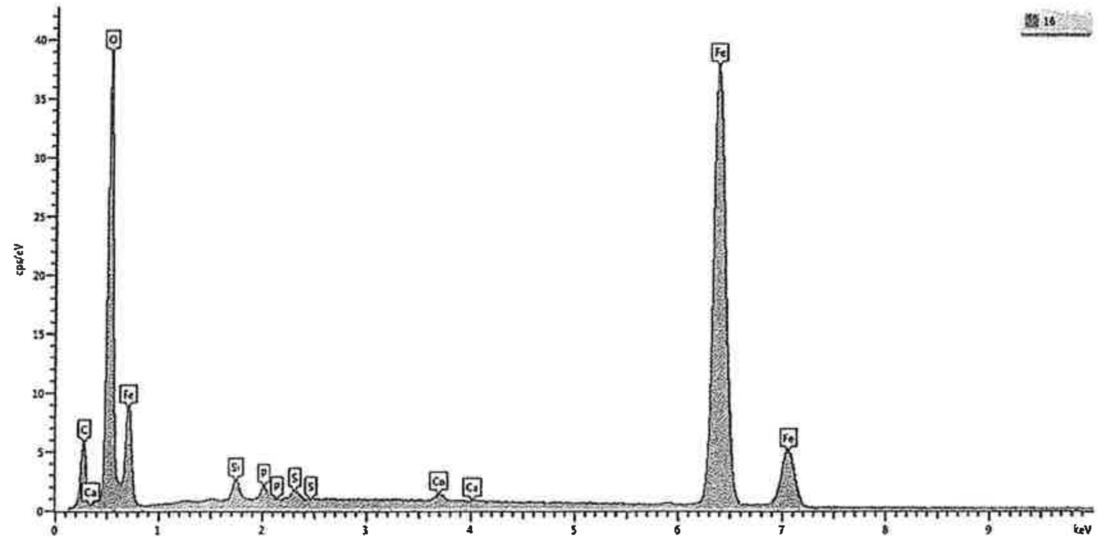


Figure 13
Analysis of Deposits from Pipe Sample 16

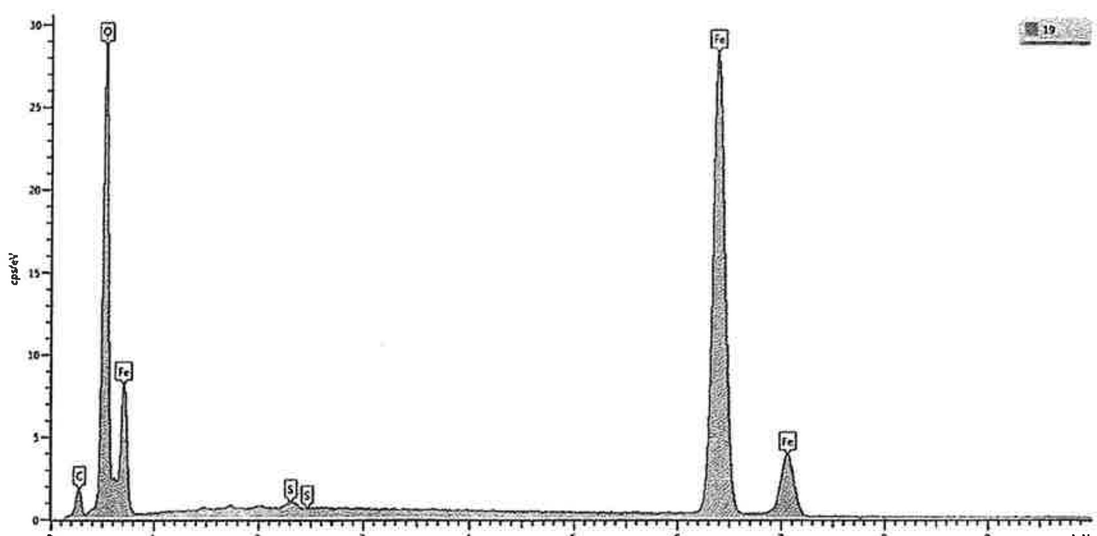


Figure 14
Analysis of Deposits from Pipe Sample 19

TABLE III

Laboratory No.: 7D83	CHEMICAL ANALYSIS	Date: 8/12/13	

Client No.: GHD000

P.O. No.: Verbal - M. Southworh

Project: GHD

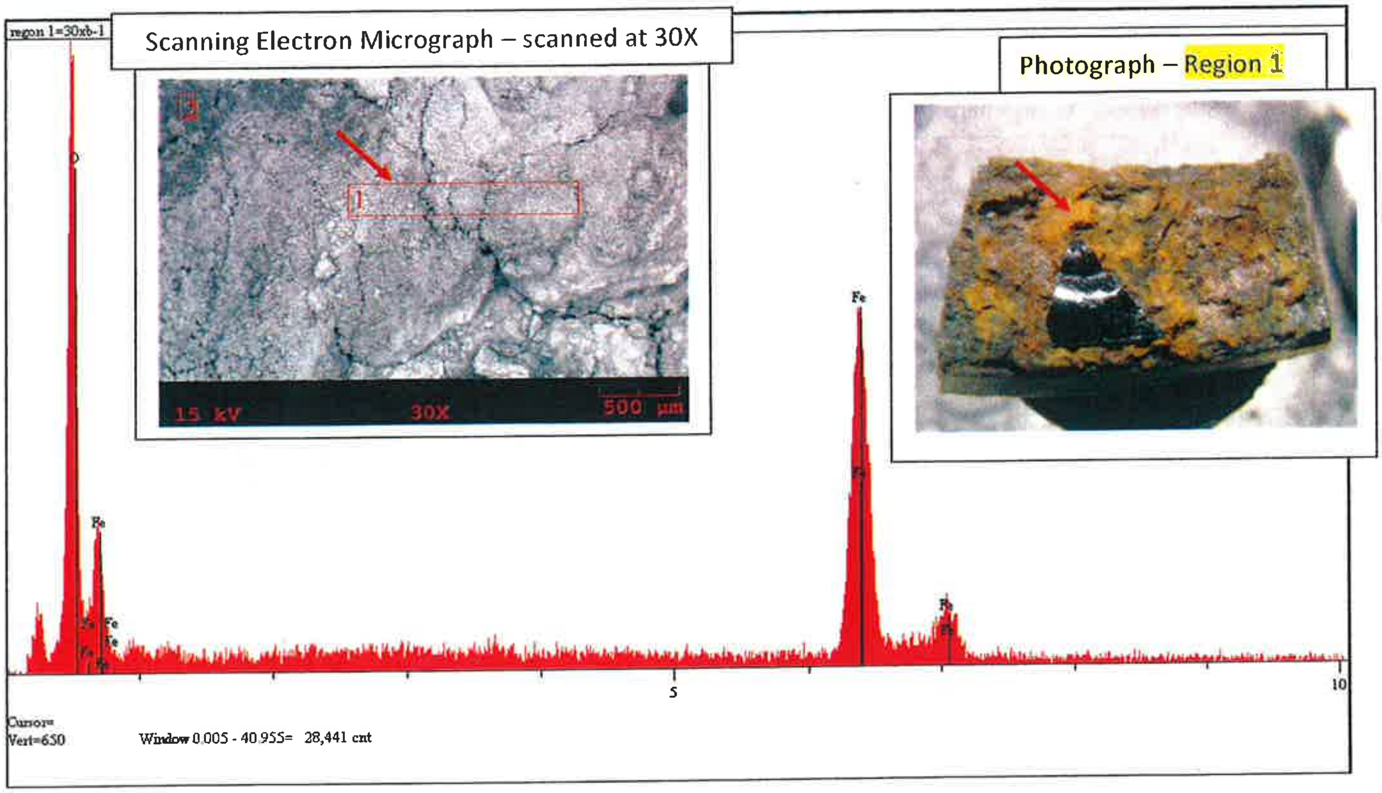
Description: Cast Iron Pipe
Specification: ASTM-A-888-13a

ELEMENT	PERCENT		SPECIFIED REQUIREMENTS	
Sample ID	Sample 5	Sample 16	Minimum	Maximum
Carbon (C)	3.67	3.60	0.00	NS
Silicon (Si)	2.09	2.19	0.00	NS
Phosphorus (P)	0.17	0.28	0.00	0.38
Sulfur (S)	0.11	0.11	0.00	0.15
Chromium (Cr)	0.17	0.15	0.00	0.50
Titanium (Ti)	0.02	0.03	0.00	0.10
Aluminum (Al)	0.04	0.08	0.00	0.50
Lead (Pb)	<0.010	<0.010	0.000	0.015
Carbon Equivalent	4.43	4.43	4.10	NS
Iron (Fe)	Balance	Balance	Balance	Balance

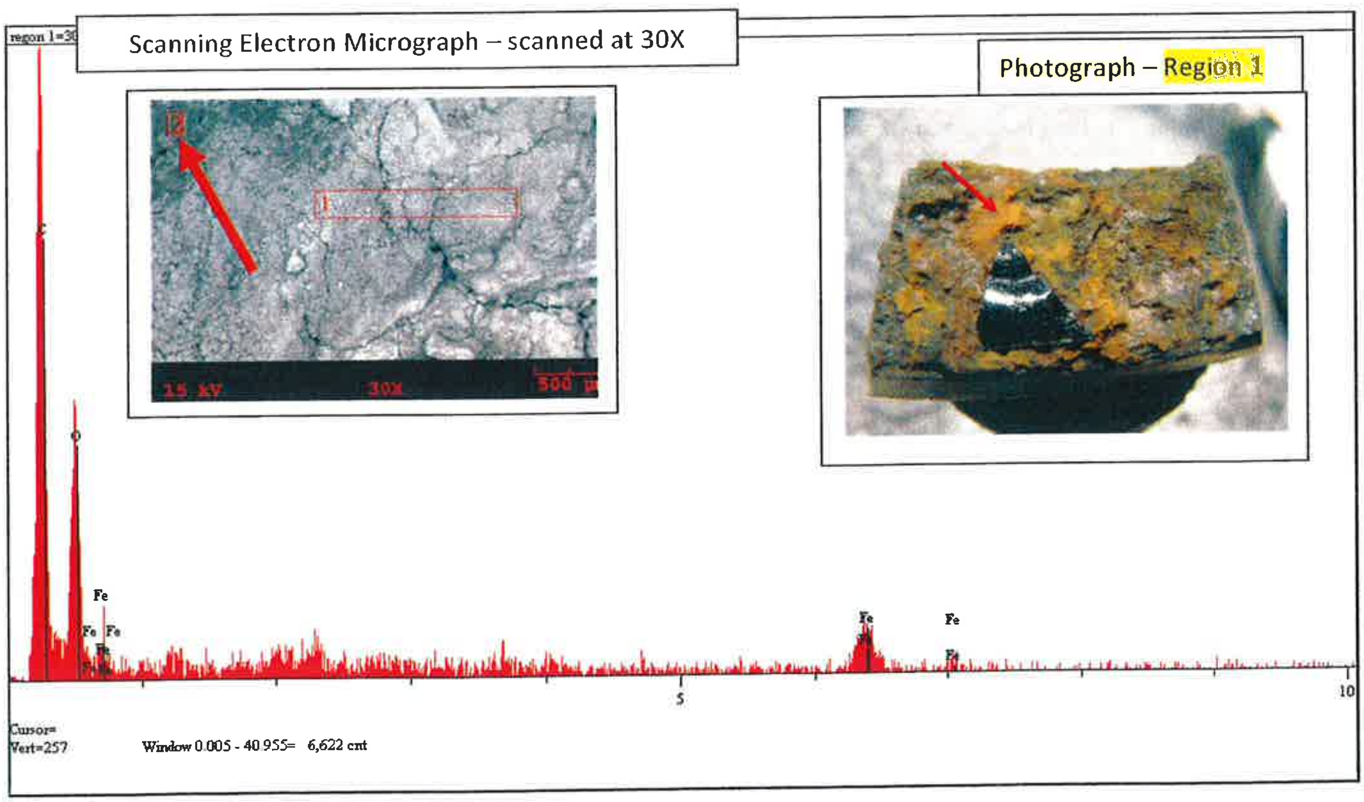
SOP 20.121

Remarks:
Results Reported To: GHD
Chemical Analysis performed by Wavelength X-ray Fluorescence as per Element Materials Technology SOP 4.00, Revison 8
Pb was performed by ICP as per Element Materials Technology SOP 17.00, Revision 13
Carbon and Sulfer performed by Combustion as per Element Materials Technology SOP 7.00, Revision 8

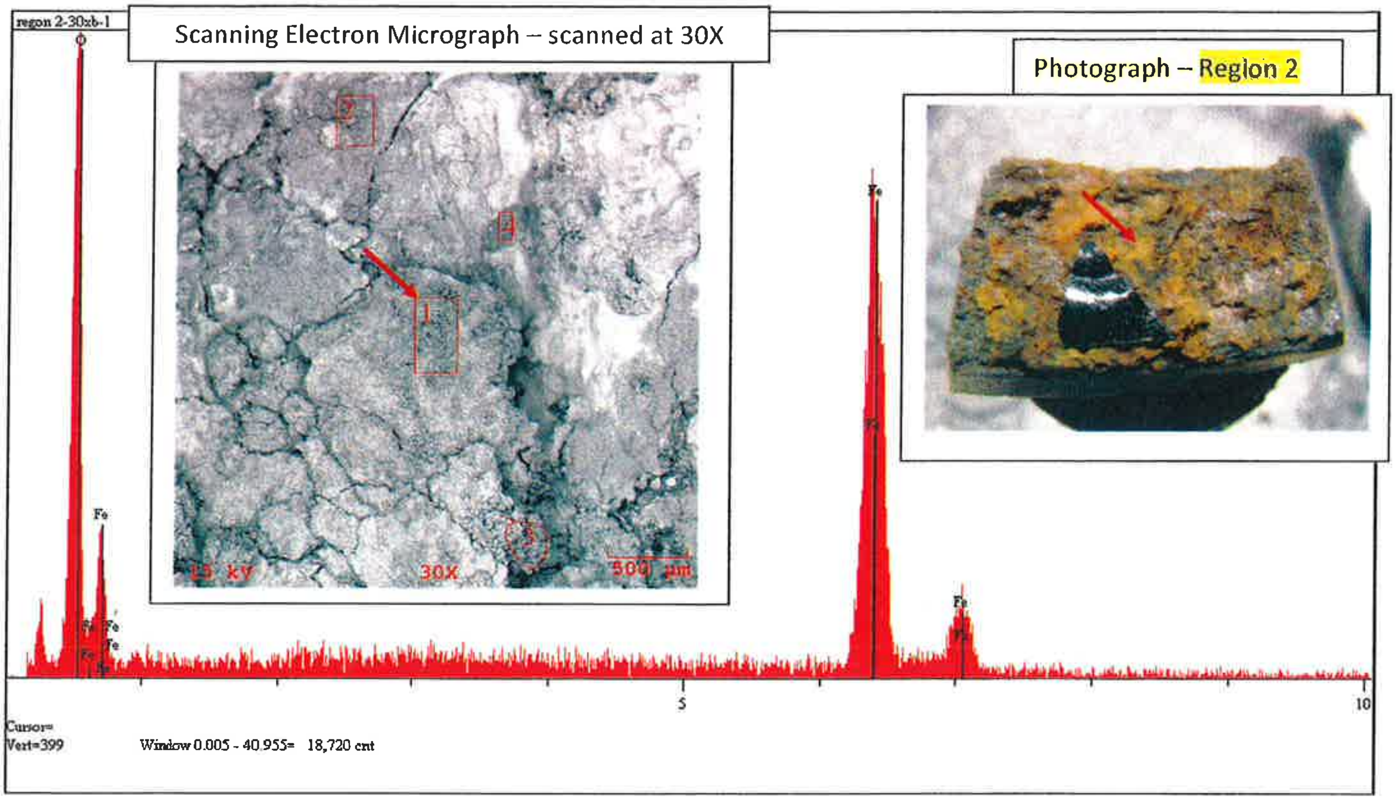
Sample 1/8 – SEM/EDS – elemental analysis – scanned at 30X – BSE detector



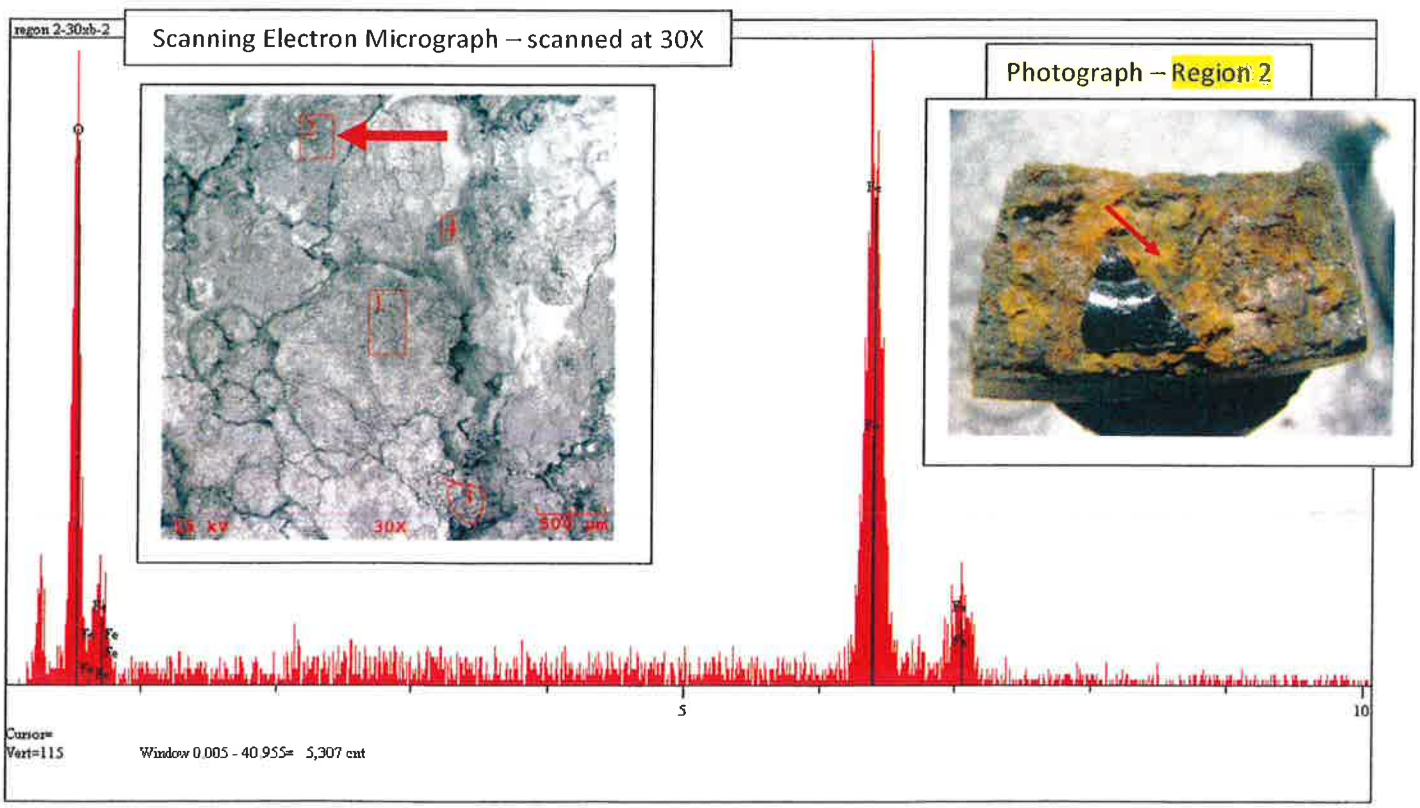
Defect region -- SEM/EDS – elemental analysis – scanned at 30X



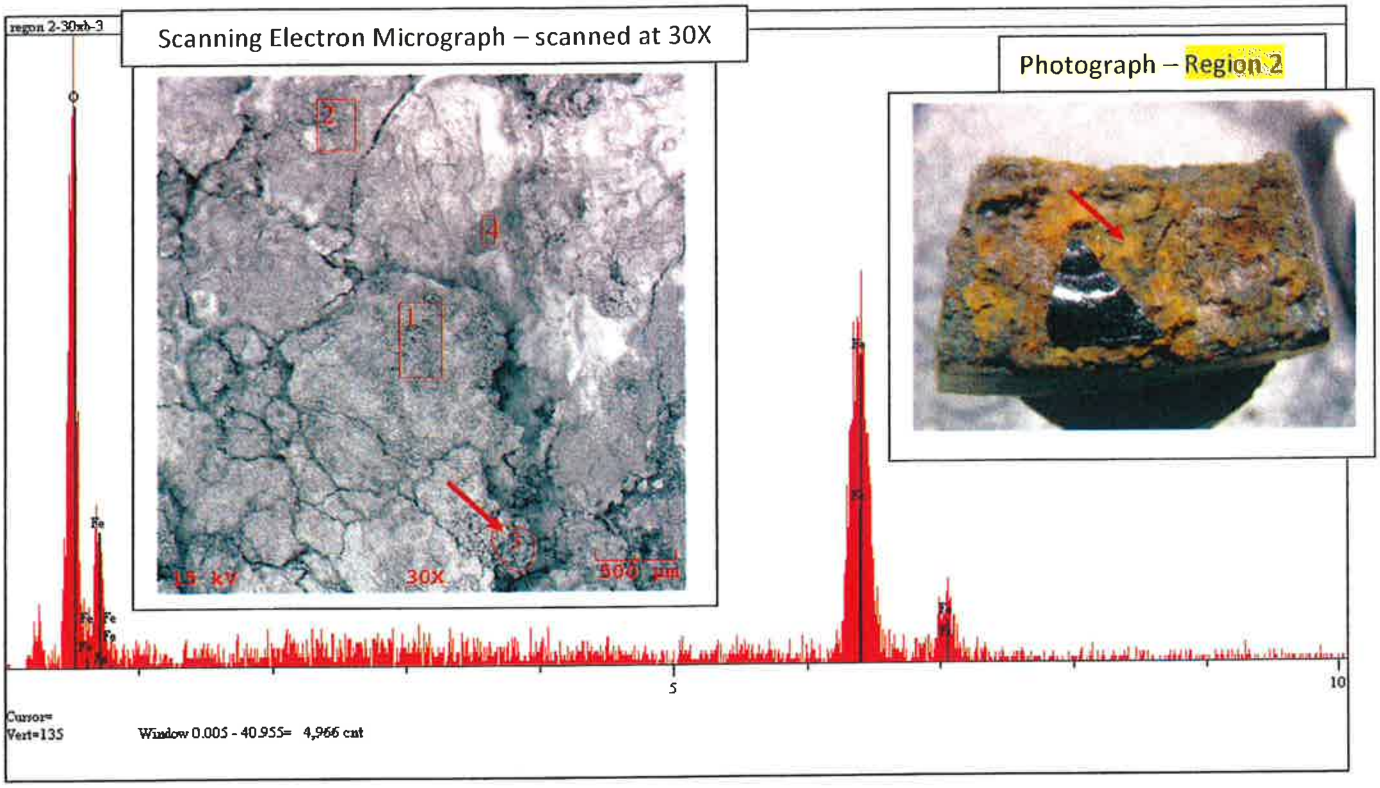
Sample 1/8 – SEM/EDS – elemental analysis – scanned at 30X – BSE detector



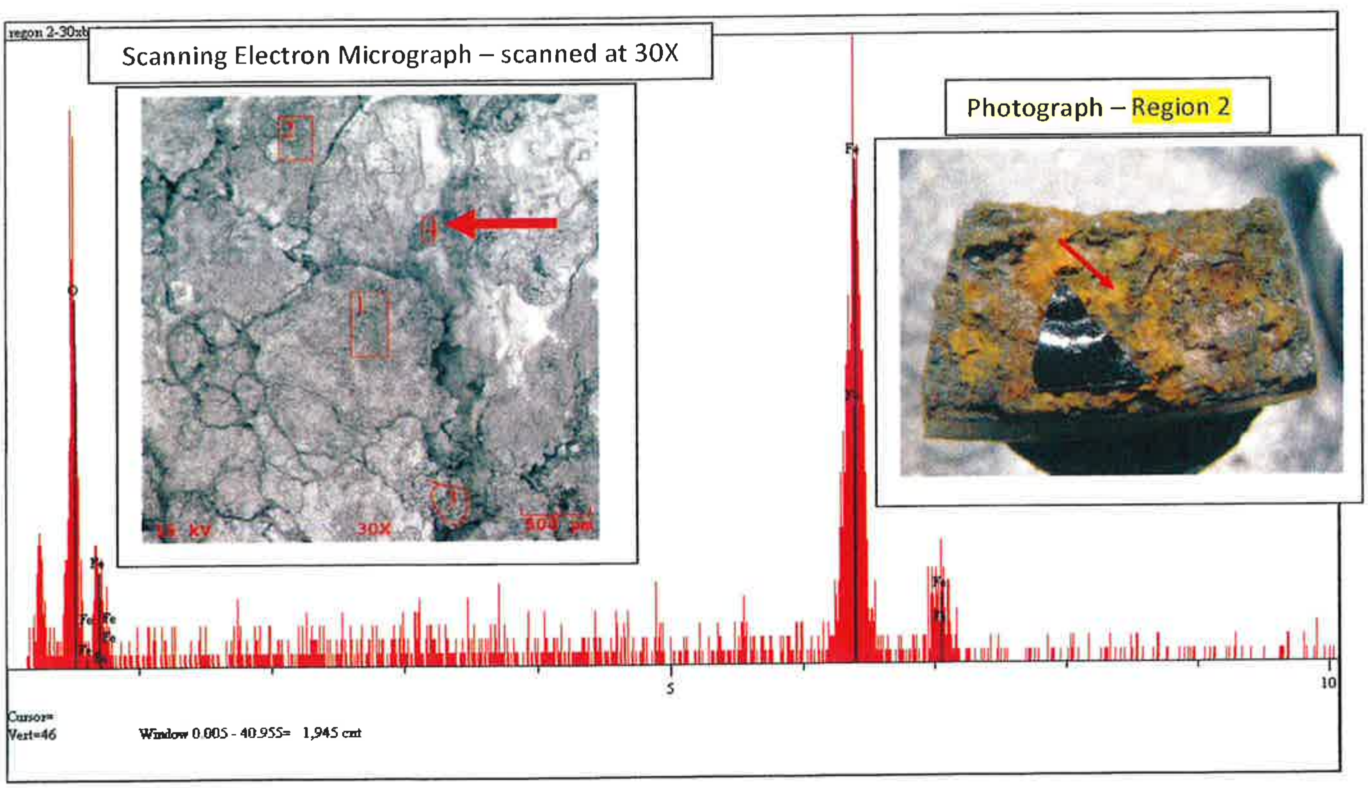
Defect region -- SEM/EDS – elemental analysis – scanned at 30X



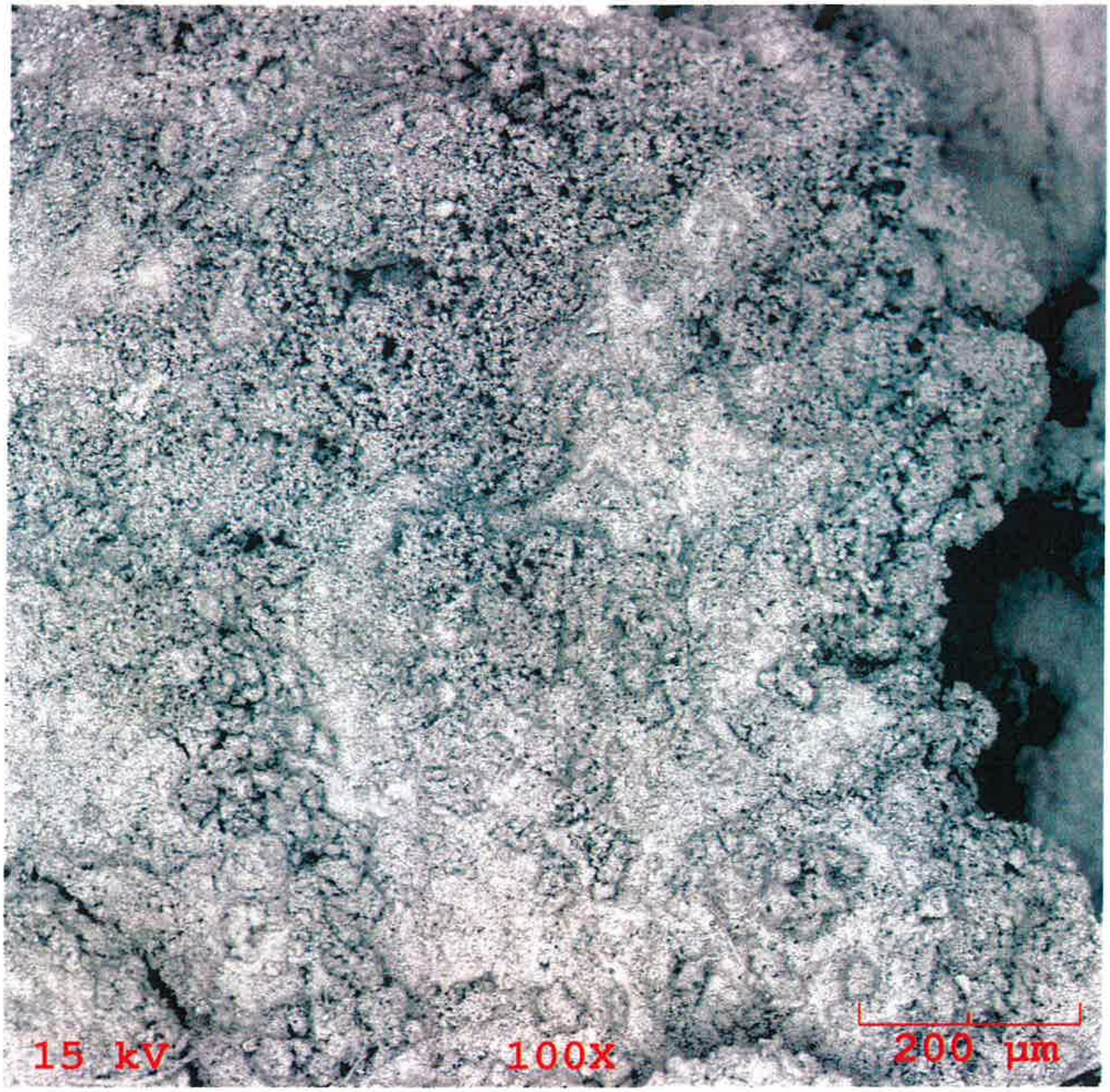
Sample 1/8 – SEM/EDS – elemental analysis – scanned at 30X – BSE detector



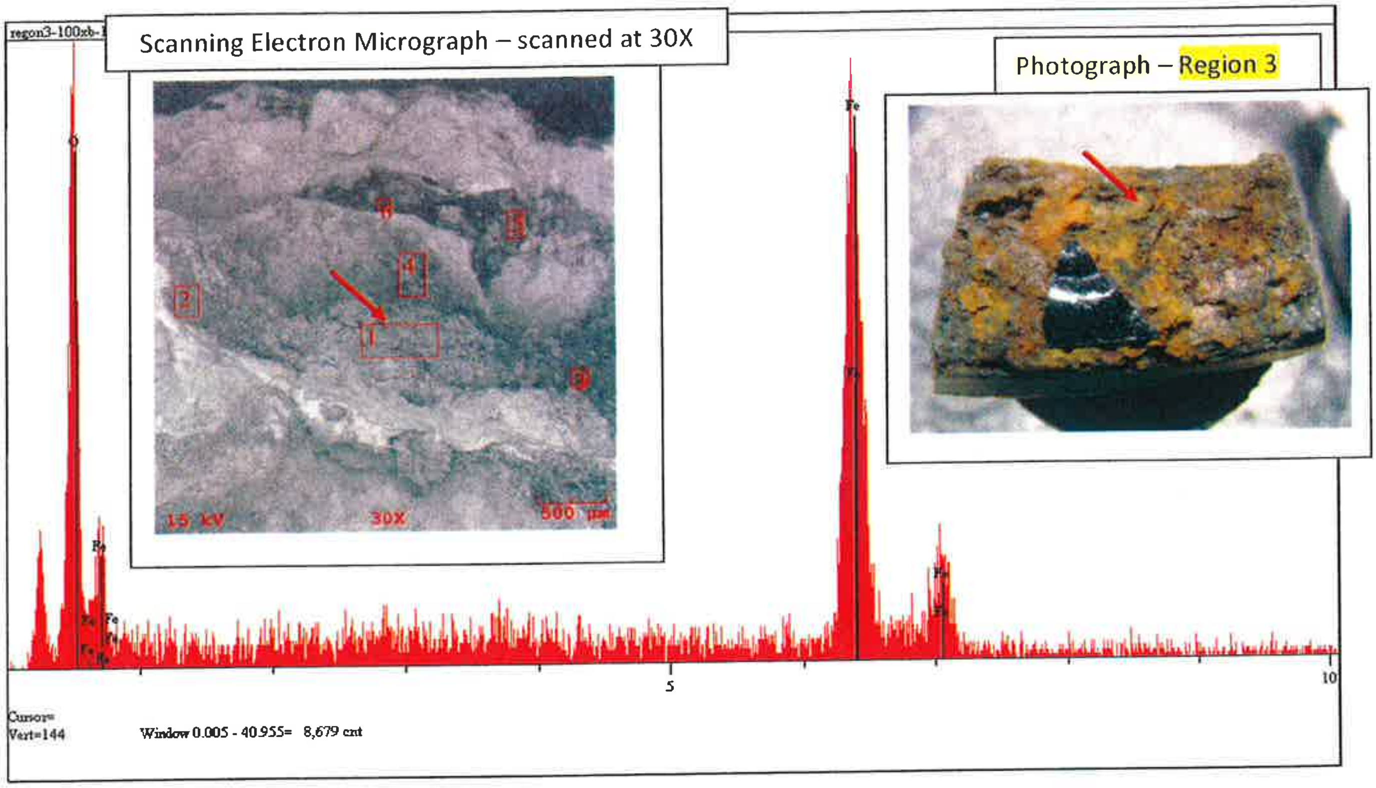
Defect region -- SEM/EDS – elemental analysis



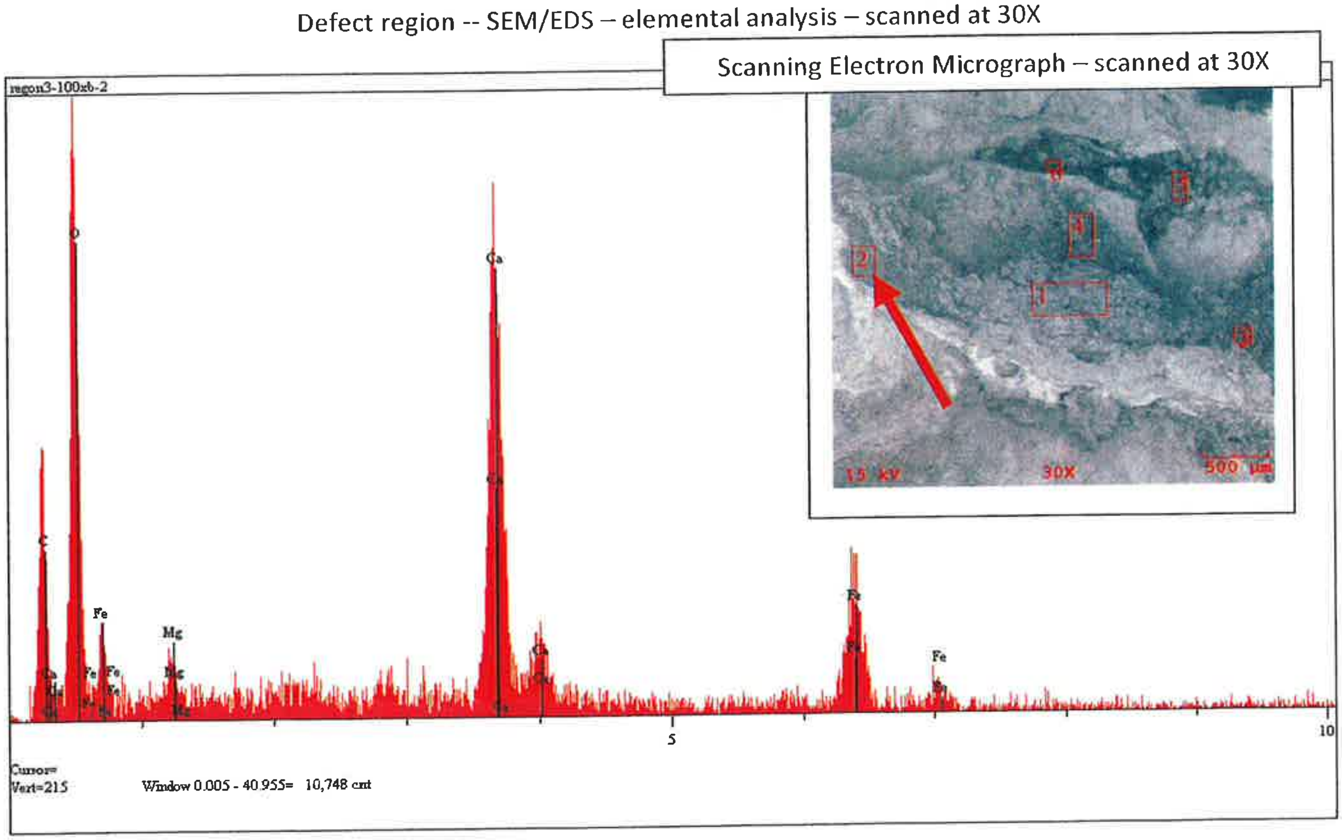
SEM Micrograph – Scanned at 100X – Region 2 from Photomicrograph



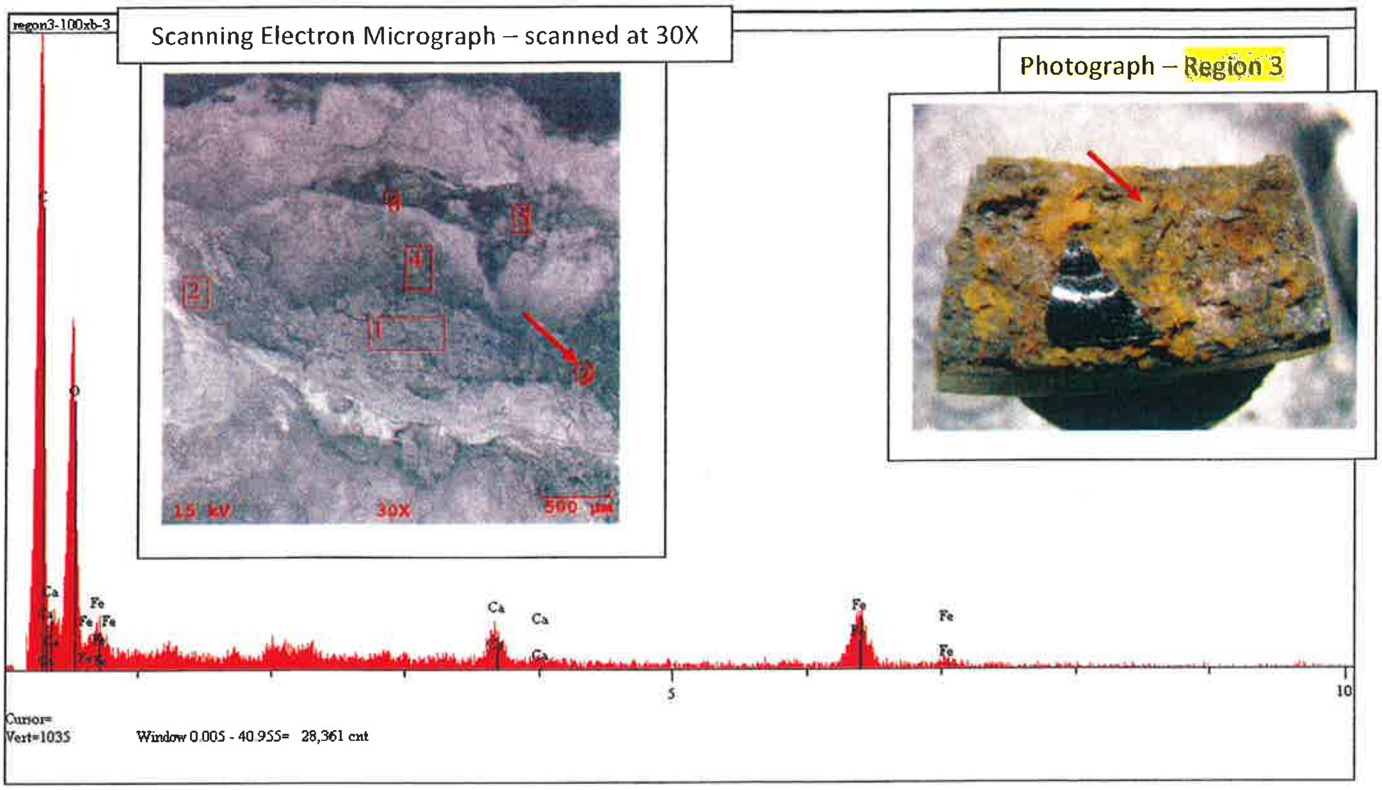
Sample 1/8 – SEM/EDS – elemental analysis – scanned at 30X – BSE detector



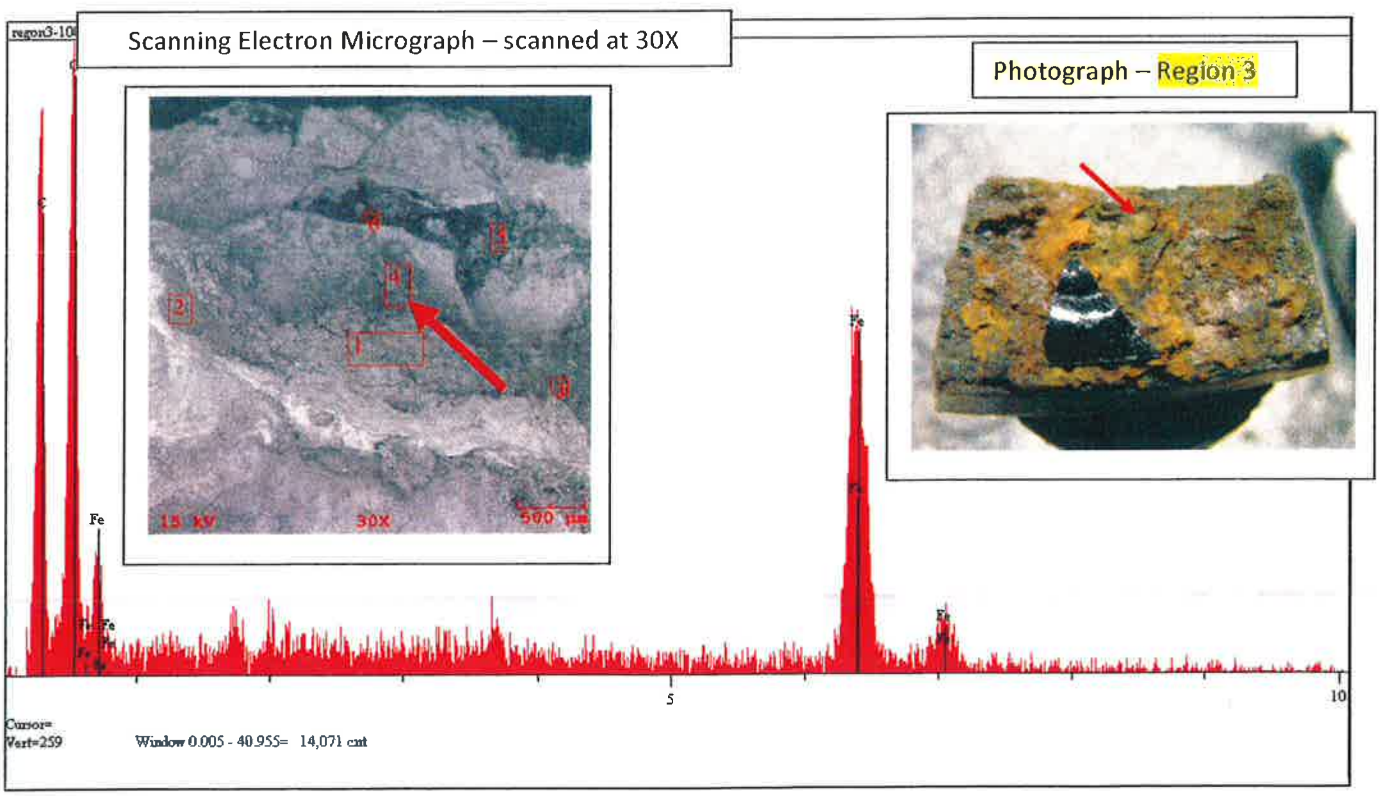
Defect region -- SEM/EDS – elemental analysis – scanned at 30X



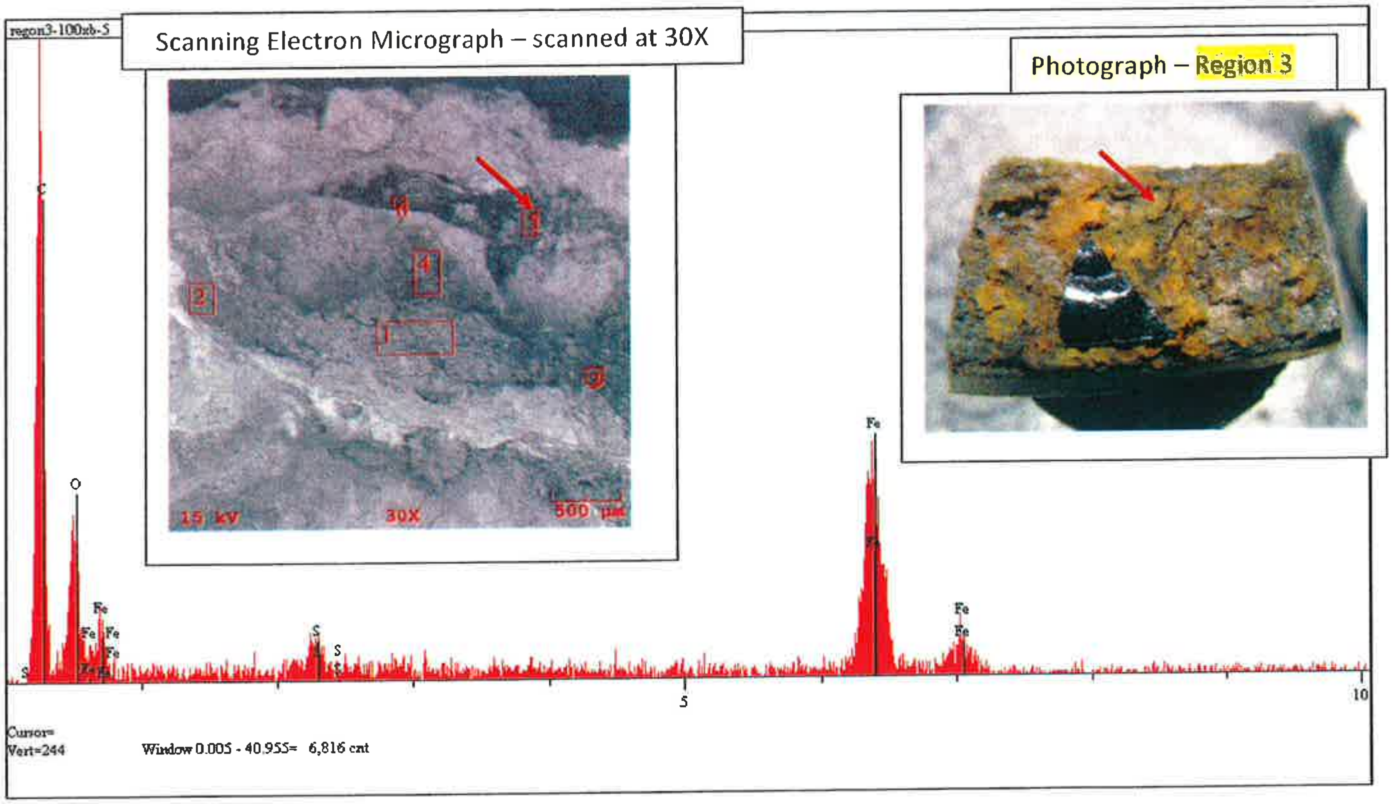
Sample 1/8 – SEM/EDS – elemental analysis – scanned at 30X – BSE detector



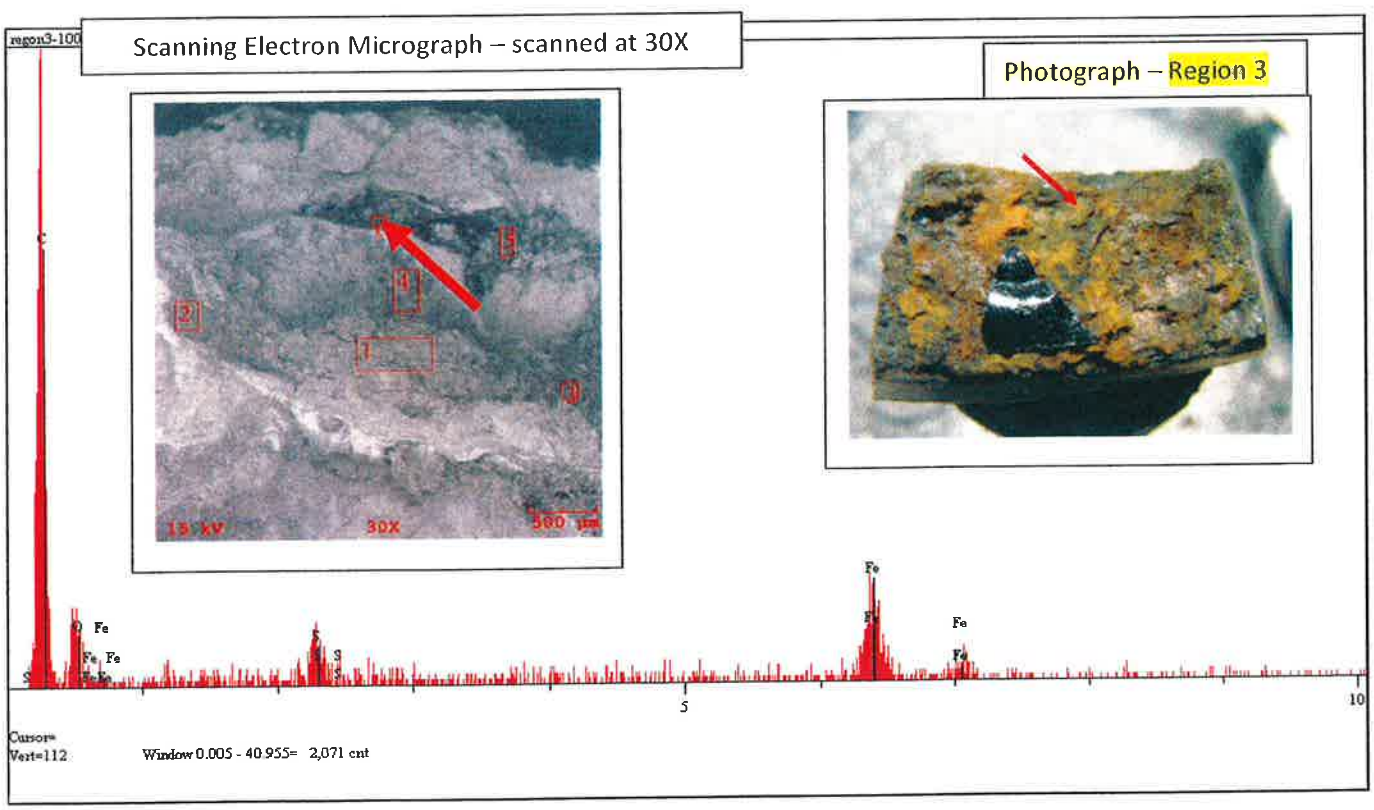
Defect region -- SEM/EDS – elemental analysis – scanned at 30X



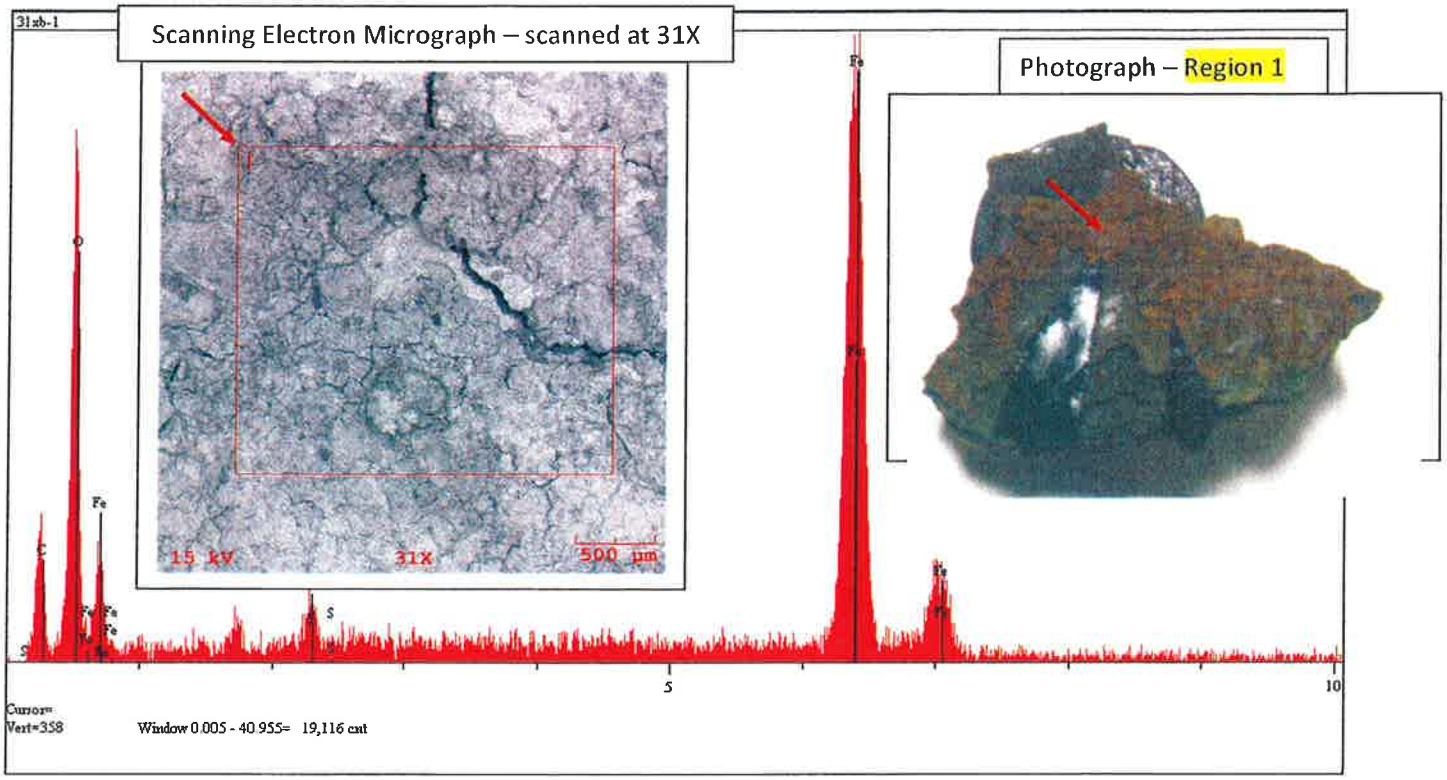
Sample 1/8 – SEM/EDS – elemental analysis – scanned at 30X – BSE detector



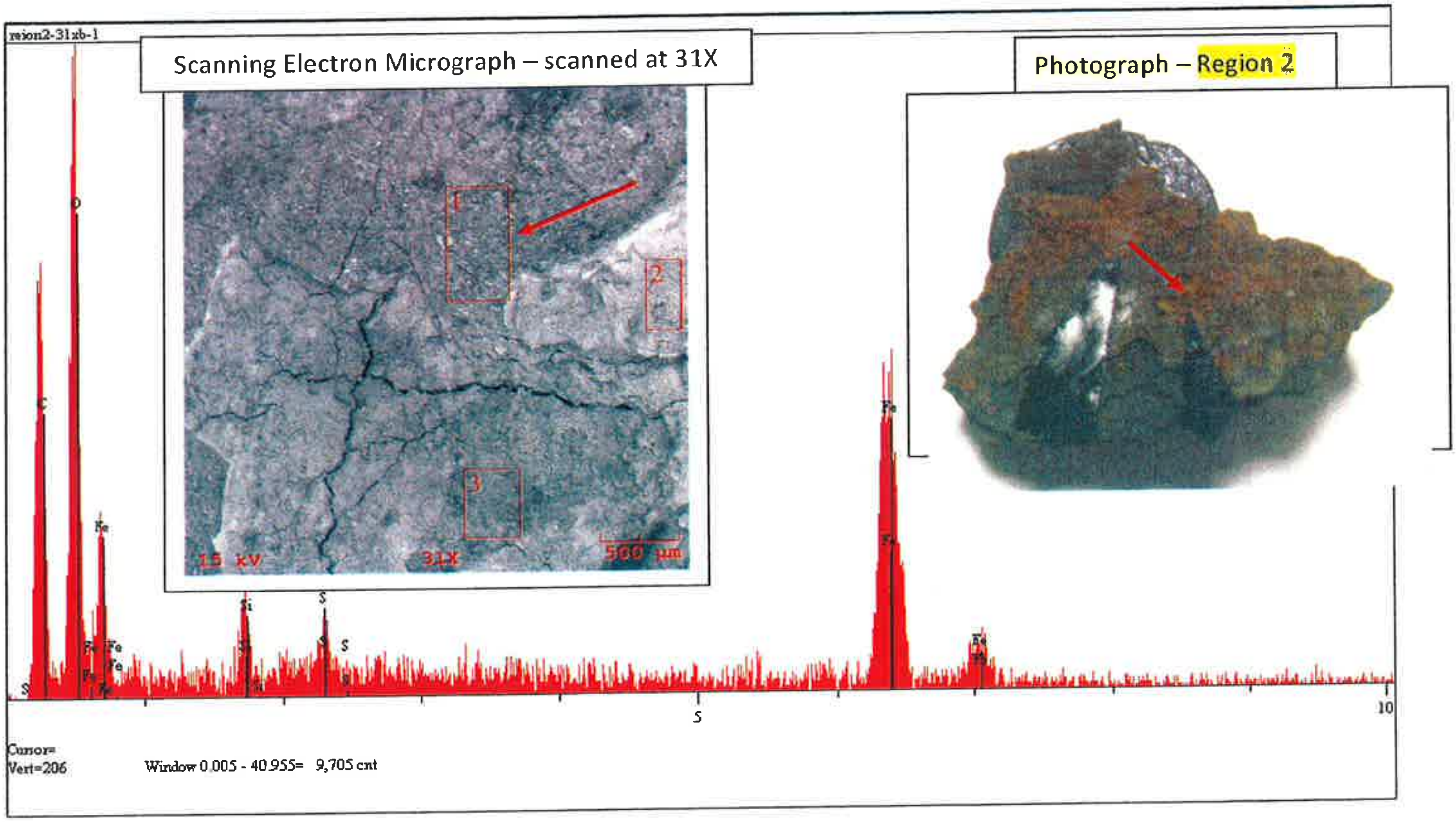
Defect region -- SEM/EDS – elemental analysis – scanned at 30X



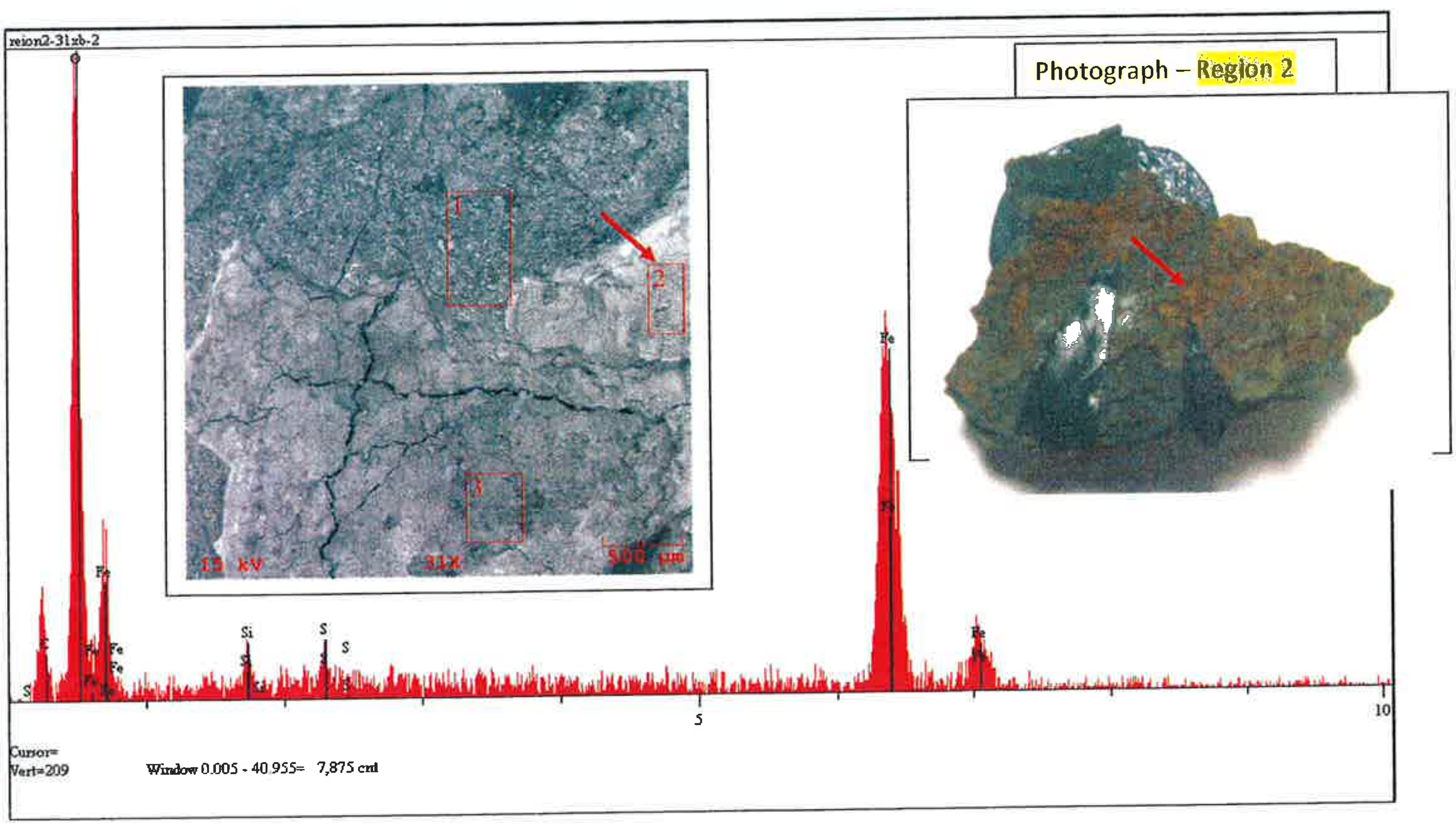
Sample T – SEM/EDS – elemental analysis – BSE detector



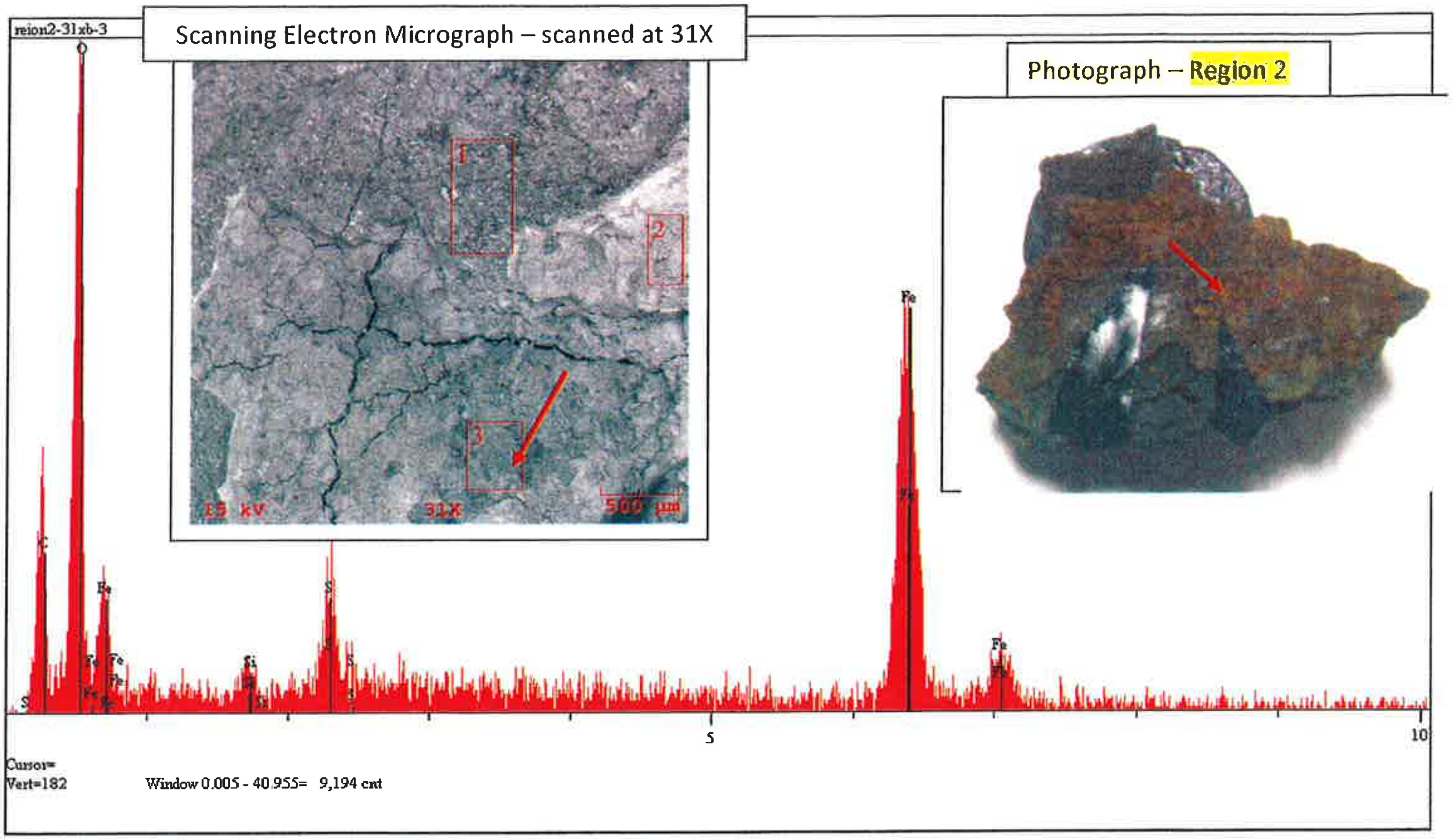
Sample T – SEM/EDS – elemental analysis – BSE detector



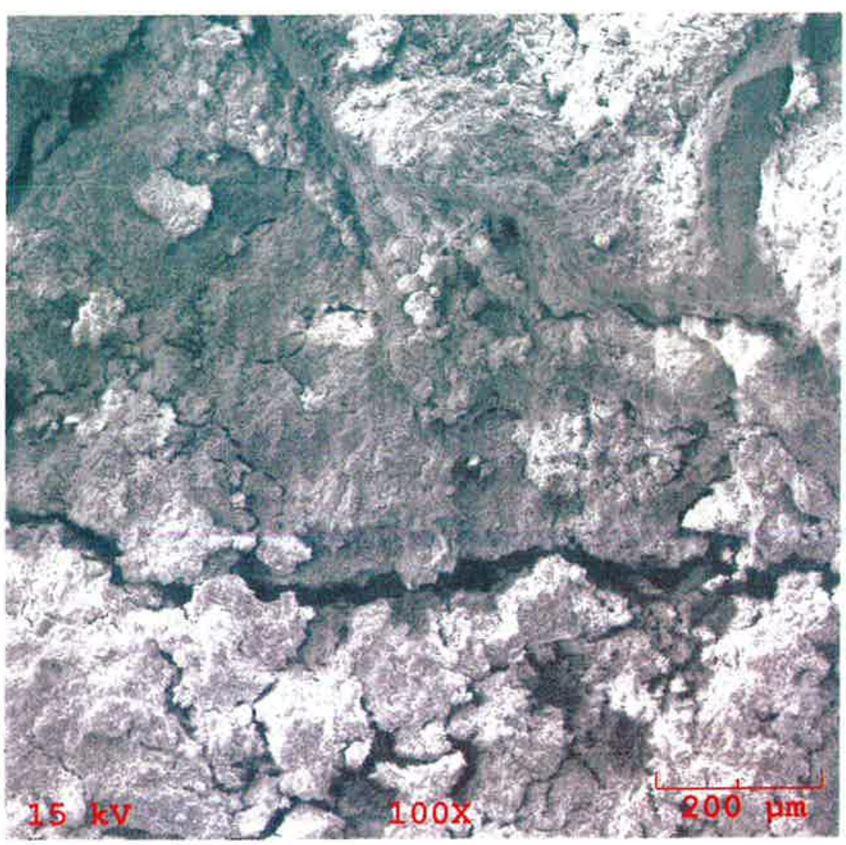
Sample T – SEM/EDS – elemental analysis – BSE detector



Sample T – SEM/EDS – elemental analysis – BSE detector



SEM Photomicrograph – scanned at 100X – ET detector



MJO: 3726 **Date:** July 13, 2012

S.O. NO: 3164121 **Customer:** DGS/RESD/BPM

Cast Iron Pipe Fittings Corrosion Analysis

Introduction: Two cast iron pipe fittings from the 4th floor sanitary line of 450 North St. (Suite 1200), Sacramento, CA 95814, were submitted to MTL for corrosion analysis. Sample #1 was a 1/8th Bend and Sample #2 was a Tee. Both exhibited extensive corrosion from the inside out (See Figures 1 & 2 below) however the Tee was the worse case having to be delivered in two pieces.

Figure 1 – Inside of 1/8th bend fitting (Sample 1).

Martin Testing Laboratories
A Division of Materials Technology Laboratories, Inc.
4724 Arnold Ave.
McClellan, CA 95652
Ph: (916) 920-4110; Fx: (916) 920-4390

Figure 2 – Sample 2 – Fourth floor Tee.

Findings:

Alloy Identification:

Chemical analysis of the metal from both samples was performed by Wavelength X-ray Fluorescence with Carbon and Sulfur determined by Combustion. The compositions of many of the various cast irons overlap because of the wide range of allowable content. This makes exact determination of the alloy difficult although I can say that the compositions were found to be typical of ductile gray cast irons. The exceptions here are the relatively large concentrations of phosphorous and sulfur which are typically controlled to less than 0.08%. The full analysis results are presented below:

Sample ID:	SAMPLE 1
Material:	CAST IRON

CHEMICAL ANALYSIS

Element		Result %
C	=	3.65
Mn	=	0.51
P	=	0.157
S	=	0.061
Si	=	2.52
Cr	=	0.14
Ni	=	0.09
Mo	=	0.03
Cu	=	0.32
Mg	=	0.01
Ti	=	0.03
Fe	=	Balance

Chemical Analysis performed by Wavelength X-ray Fluorescence per SOP 4.00, Revision 8
Carbon and Sulfur by Combustion per SOP 7.00, Revision 7

FOR INFORMATION ONLY

Sample ID:	SAMPLE 2
Material:	CAST IRON

CHEMICAL ANALYSIS

Element		Result %
C	=	3.56
Mn	=	0.53
P	=	0.135
S	=	0.162
Si	=	2.45
Cr	=	0.21
Ni	=	0.10
Mo	=	0.03
Cu	=	0.21
Mg	=	0.01
Ti	=	0.02
Fe	=	Balance

Chemical Analysis performed by Wavelength X-ray Fluorescence per SOP 4.00, Revision 8
Carbon and Sulfur by Combustion per SOP 7.00, Revision 7

FOR INFORMATION ONLY

Metallurgical Cross-Sections:

A sample from each fitting was sectioned out and mounted in cross-section in epoxy. The cross-section was polished down to 4000 grit then etched using nital solution. Both of the samples displayed an intact layer of brittle graphite and corrosion products. This layer is indicative of graphitic corrosion in gray iron in which the iron matrix is selectively leached away, leaving a porous mass of graphite.

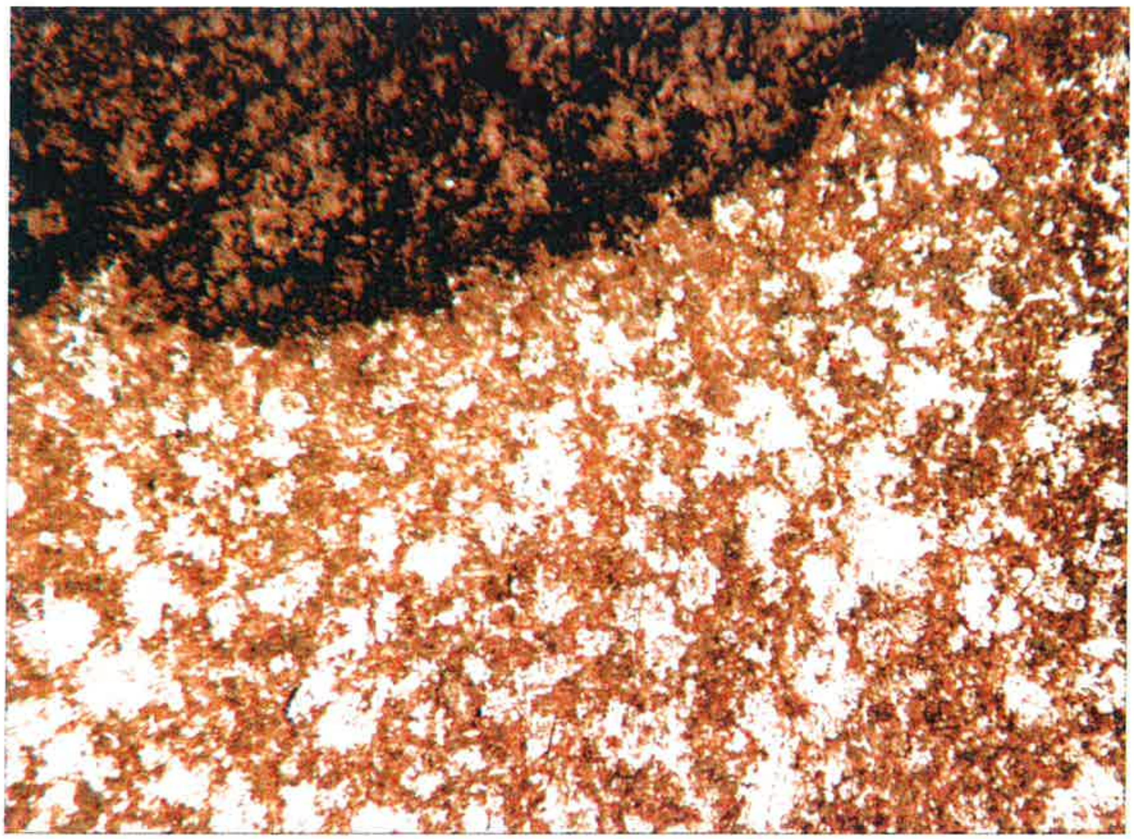


Figure 3 – Sample 1 at 100x. Black at top left is an intact porous layer of corrosion product & graphite. "Brighter" material is compromised base metal that has not yet been completely leached away.

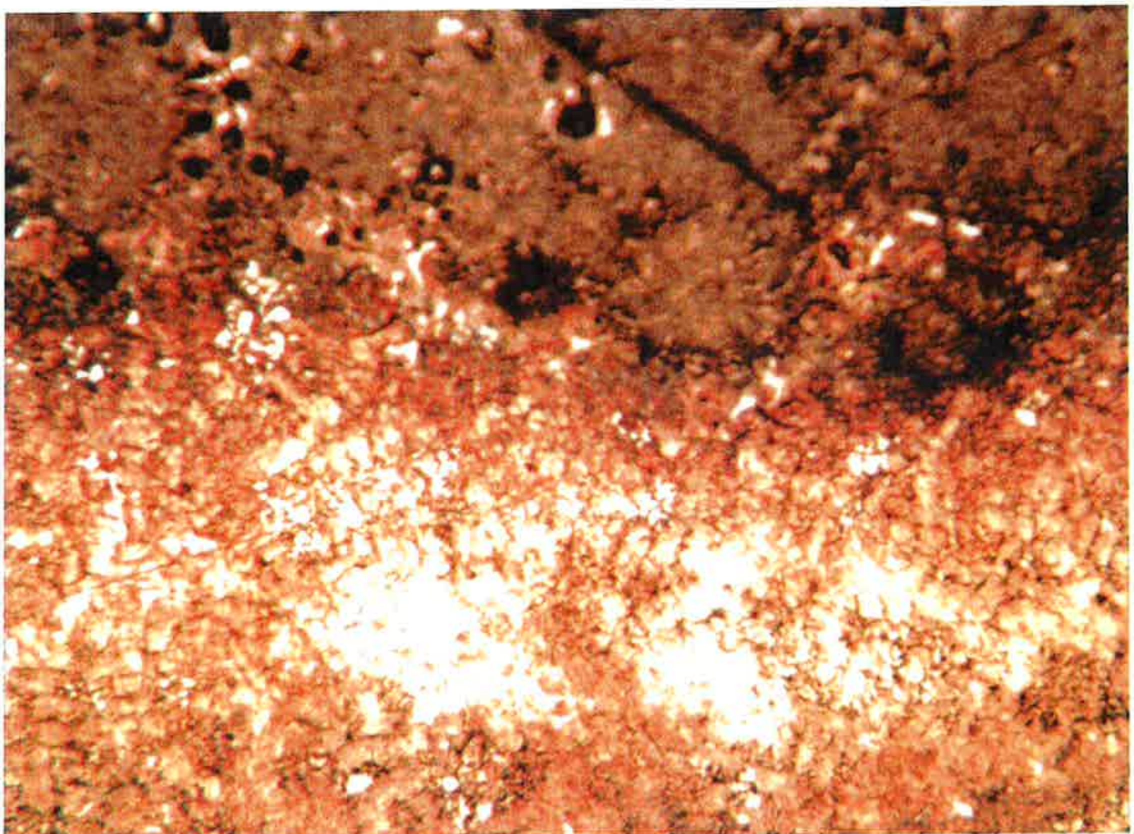


Figure 4 – Sample 2 at 200x. Close-up of the graphite (top)/ compromised metal interface.

Scanning Electron Microscope (SEM)/Energy Dispersive Spectroscopy (EDS) Analysis:

The full analysis will be available in Appendix I & II which will come as separate documents because of the size. Small amounts of sulfur were found in both samples. This may be indicative of hydrogen sulfide (sewer gas) contributing to the problem.

Conclusions:

The problem identified is Graphitic Corrosion. Graphitic corrosion is a form of dealloying unique to cast irons. It is observed in gray cast irons in relatively mild environments in which the selective leaching of iron leaves a porous graphite network. Selective leaching of the iron takes place because the graphite is cathodic to the iron making for an excellent galvanic cell. This form of corrosion generally occurs only when corrosion rates are low. If metal corrodes more rapidly, the entire surface, including the graphite is removed, and uniform corrosion occurs.

Experience has demonstrated that graphitic corrosion is favored by relatively mild environments such as soft waters, waters having a slightly acidic pH, waters having low levels (as little as 1 ppm) of hydrogen sulfide, and brackish and other high conductivity waters. A small amount of sulfur was detected in the corrosion products.

Recommendations for Prevention:

Alloy selection – White cast iron is immune to graphitic corrosion although it is susceptible to other forms.

Control of the environment – water traps could reduce or eliminate corrosion gases, raising the pH (via alkaline drain cleaners) is an inexpensive approach.

Use of sacrificial anode cathodic protection or impressed current cathodic protection.

Prepared By:

Perry L. Martin
Materials Engineer

Appendix F – Author and Peer Reviewer Curriculum Vitae

Laws & Associates, Inc.
Mechanical Consulting Engineers

A. Calvin Laws, P.E.
Chief Executive Officer

EXPERIENCE

Over thirty years experience in engineering design and construction of heating, refrigeration, air-conditioning, plumbing, fire protection and process piping systems with consulting engineering and contracting firms. As CEO of Laws and Associates, Inc., involvement includes administration plus engineering in a broad range of building types such as commercial, institutional, residential and industrial projects.

REGISTRATION

Registered Professional Mechanical Engineer in the states of California, Colorado, Massachusetts, Illinois and Arizona.

EDUCATION

California Polytechnic State University
Bachelor of Science Mechanical Engineering - 1962

AFFILIATIONS

- American Society of Heating, Refrigeration and
- Air Conditioning Engineers
- American Society of Plumbing Engineers
- *National Society President 1980 - 1984*
- National Fire Protection Association
- Society of Fire Protection Engineers
- Construction Specification Institute

TEACHING

San Francisco City College
Engineering Technology Department
Part-Time Instructor
1974 to present

1801 Murchison Drive
Suite 160
Burlingame, CA 94010
Phone (650) 697-5691
Fax: (650) 697-5692
www.lawsandassociatesinc.com

Michael Southworth
Mechanical Engineer

Proposed Responsibility
Mechanical Engineer

Education
B.S./1981/Environmental Engineering/California Polytechnic State University, San Luis Obispo/CA
1986/ASHRAE Certification Course
1988/Certified Plumbing Engineer

Professional Registration
Mechanical/CA/#26321
U.S. Green Building Council LEED Accredited Professional

Memberships
ASHRAE
ASPE
USGBC

Experience

Mr. Southworth has worked as a design/consulting engineer for 22 years. His work has included HVAC, plumbing, process piping, solar heating systems and fire protection design. In addition, he has performed comprehensive energy audits for light commercial to heavy industrial facilities and reviewed both residential and commercial building designs for code compliance. Project designs involved performing computerized building heating and cooling load calculations, duct and piping layout, equipment layout and selection and project specifications. Recent projects include heating and piping renovations, forensic investigation of mechanical systems, and building commissioning.

Representative experience for Mr. Southworth includes:

- **Mechanical System Upgrade for the San Diego County Department of General Services, San Diego, CA.** Performed project engineering services for the upgrade of the central HVAC plant at a 200,000 square foot County Annex facility. Directed an extensive field survey of existing mechanical and electrical equipment, and managed the design and issue of Contract Drawings and Specifications for new chillers, cooling towers, boilers, air handlers, pumps, and controls. Resolved difficult access issues in the removal of existing equipment and in the installation of new equipment in an existing concrete structure over 40 years old. Corrected comfort problems experienced throughout the facility due to poor air and water distribution, and upgraded the controls to state of the art digital controls. Increased equipment efficiencies overall by a large margin, which qualified the client for rebates and financial incentives from the local utility, and which will provide significant operating cost savings.

- **Port Improvements at Port Hueneme Naval Base, Oxnard, CA.** Developed design-build drawings and specifications for the new construction of (2) 200 HP steam generation plants and distribution systems. Wrote performance specifications for the boilers, appurtenances, steam piping, condensate return, natural gas, water, sewer, power, and equipment enclosure which will all perform to supply steam to berthed ships in the harbor. Reviewed Contractor's submittals for conformance to the intent of the Contract Documents. Witnessed equipment performance testing and inspected equipment installation.

- **Operations Center HVAC Upgrade, Oakland, CA.** Mechanical engineer for mechanical and electrical engineering services to EBMUD to upgrade its Operations Center HVAC system. This existing facility houses the District's main effluent pumps, as well as locker rooms, control room, training center and offices. Investigated and evaluated reported deficiencies. Recommended various alternatives to remedy the issues and provide a reliable HVAC system. The existing constant volume reheat system was converted to a variable air volume reheat system with variable speed drives.

- **Sonoma County Administration Building, Santa Rosa, CA.** Mechanical engineer for 20,000-SF renovation of mechanical and plumbing systems. HVAC design included interface with central plant chilled water storage and heat recovery hot water systems.

- **Next Level Communications, Rohnert Park, CA.** Mechanical engineer for design of HVAC and plumbing systems for a 40,000-SF communications equipment manufacturing facility.

Michael Southworth
Mechanical Engineer

- **Sonoma County Morgue, Santa Rosa, CA.** Mechanical Engineer for renovation of HVAC system to 100% outside air with air-air heat recovery, including special constraints and sequencing of construction.

- **Coopers & Lybrand, Office Renovation, San Francisco, CA.** Mechanical engineer for the design of HVAC and fire protection systems for a 5-floor renovation in a high-rise building in the financial district. Included offices and data centers with raised floors, dedicated HVAC, and pre-action fire protection.

- **Kaiser MOB Radiology, Petaluma, CA.** Mechanical engineer for expansion of film processing lab and troubleshooting of ventilation systems in an existing medical clinic. Exhaust, plumbing and electrical systems were renovated for new lab equipment and local exhaust problems were solved.

INTERACTIVE RESOURCES

Architects & Engineers

THOMAS K. BUTT, FAIA, LEED AP BD+C

PRESIDENT
PRINCIPAL-IN-CHARGE
ARCHITECTURE DIVISION
ARCHITECT, LEED® AP

EDUCATION

- Master of Architecture, Urban Design, University of California, Los Angeles, 1973
- Bachelor of Architecture and Bachelor of Arts, University of Arkansas, 1968
- Engineer Officer Basic Course, U.S. Army Corps of Engineers, Ft. Belvoir, Virginia, 1968

CERTIFICATION

- Licensed Architect (California, Arkansas, and Nevada)
- Certification, National Council of Architectural Registration Boards
- Licensed General Contractor, California #290922
- LEED Accredited Professional

PROFESSIONAL EXPERIENCE

- Interactive Resources, 1973-present
- Mayhew and Thiederman, Architects, Inc., San Francisco, 1970-71
- Edward Durell Stone, Inc., Palo Alto, 1967-70
- U.S. Army Corps of Engineers (military service), 1968-70
- Department of the Interior, National Park Service, 1963-66

PROFESSIONAL ORGANIZATIONS

- American Institute of Architects, Elected to the College of Fellows, 1995
- Construction Specifications Institute (CSI)
- National Trust for Historic Preservation
- Western Construction Consultants Association (WESTCON), Charter Member
- American Society for Testing and Materials (ASTM), Committee E-6, Performance of Buildings, C-11, Gypsum and F-06, Floor Coverings
- International Code Council (ICC)
- Roof Consultants Institute (RCI)
- American Society of Heating, Refrigeration and Air Conditioning Engineers, Inc. (ASHRAE)
- Congress for the New Urbanism

OTHER ORGANIZATIONS

- Arkansas Alumni Association, life member and past president, Bay Area Chapter

HONORS AND AWARDS

- Arkansas Alumni Association 2005 National Community Service Award
- Arkansas State Senate Citation for a "distinguished career filled with notable accomplishments."
- Arkansas Traveler
- ASTM Award of Appreciation for Outstanding Service
- Hall of Honor, Fayetteville Public Education Foundation
- East Bay Chapter of the American Institute of Architects Practice and Technology Achievement Award for "determination to explore issues of building technology and his efforts devoted toward sharing his findings with the public and the profession."
- West Contra Costa Unified Education Fund Distinguished Citizen Award
- Coast Guard Meritorious Public Service Award
- President of the United States Award for Outstanding Community Achievement of Vietnam Era Veterans
- National Trust for Historic Preservation Honor Award
- Grand Award (Interactive Resources, Inc) for Design Excellence, National Association of Industrial and Office Parks
- Department of Transportation Award (East Brother Light Station, Inc.) for Outstanding Public Service to Transportation and Historic Preservation

DIAGNOSTIC ARCHITECTURE AND CONSTRUCTION TECHNOLOGY

- More than 350 consulting assignments relating to construction failure or construction litigation, including 10,000 units of housing.
- Expert witness in over 100 construction litigation cases, including trial testimony in California and Oregon courts
- Serves on three committees and chairs two ASTM task groups related to moisture problems in buildings
- Arbitrated dozens of construction disputes through the auspices of the American Arbitration Association, served on its panel of arbitrator trainers, and as a faculty member in continuing education of arbitrators.

REPRESENTATIVE NEW AND REHABILITATION BUILDING DESIGN

- Limoneira Solar Project (LEED Gold), Santa Paula, CA
- Emerson School Solar Project, Berkeley, CA
- 801-851 Traeger Façade Restoration, San Bruno, CA

- Oak Grove Apartments Construction Defect Repairs, Healdsburg, CA
- BART Leak Investigations - Powell Street, Pleasant Hill and Richmond Stations
- The Landing at Jack London Square, Construction Defect Repairs, Oakland, CA
- Mariner Square and Baltic Square, Richmond, CA
- College of San Mateo Building 18 Rehabilitation, San Mateo, CA
- Margaret Lesher Student Union Building, Diablo Valley College

HISTORIC PRESERVATION

- National Trust for Historic Preservation volunteer in New Orleans Katrina Damage Assessment Team, 2005
- Completed more than 100 projects involving restoration or rehabilitation of historic structures, many of which are listed on the National Register of Historic Places.
- Lectured widely on historic preservation practice to groups including the National Trust for Historic Preservation Annual Convention, the Monterey Design Conference, and many civic clubs and organizations.
- Prepared and administered numerous successful grant applications for historic preservation projects and National Register Nominations and Certifications.

ENERGY CONSERVATION AND ALTERNATIVE ENERGY APPLICATIONS

- Early work in alternative energy and energy conservation set the pace in California in the years immediately following the energy crisis of 1973, influencing subsequent state energy conservation legislation and speeding the incorporation of energy conservation considerations into the mainstream of California architectural practice.
- Completed more than 100 projects between 1973 and 1983 that incorporated cutting-edge active and passive solar, wind, and other energy conservation technology. Those included private homes, apartments and condominiums, commercial and public buildings, and swimming pools. Many have been published in local, regional, and national media.
- In 1975, organized and implemented the first statewide California Solar Energy for Buildings Conference, repeated in 1976 and 1977 with hundreds of building industry professionals attending.
- Secured six U.S. Government-sponsored grants for research or demonstration projects in solar energy.

CURRENT PUBLIC SERVICE

- City of Richmond City Council, Elected Member and Vice-Mayor, Richmond City Council, 16 years. Served as vice-mayor twice and chair of Public Safety/Public Services Committee, Rules and Procedures committee, Personnel Committee and Finance Committee
- BCDC Commissioner (Alternate to Tom Bates, Mayor of Berkeley)
- Contra Costa LAFCO Commissioner (Alternate to Contra Costa Conference of Mayors representatives)
- Best Local Politician, *East Bay Express*, May 2004
- Board of Directors, Local Government Commission, Chair 2008-10
- Board Member, Rosie the Riveter Trust, President 1999-2011
- Board Member, President, East Brother Light Station, Inc.

PAST PUBLIC SERVICE

- City of Richmond representative, West Contra Costa Transportation Advisory Committee (WCCTAC)
- Commissioner for Qualifications Appraisal Interviews, California State Board of Architectural Examiners
- Chair, West County Agency
- District Chairman, Herms District, Diablo-Silverado Council, Boy Scouts of America
- Board of Directors, Richmond, California, Chamber of Commerce
- Chairman, Richmond Economic Development Commission
- President, Washington School PTA
- President, Point Richmond Business Association
- President, Point Richmond Neighborhood Council
- Board of Arbitrators, American Arbitration Association
- Citizen's Advisory Committee for Richmond, California Shoreline Conservation and Development Plan, the Knox Freeway-Cutting Boulevard Corridor Study, and the North Richmond Shoreline Specific
- Richmond CETA Advisory Committee
- Richmond Community Development Commission
- Richmond Rotary Club, past President

PUBLICATIONS

- Vinyl Windows May Exacerbate Water Intrusion in Stucco Walls
- Thomas K. Butt, "Water Resistance and Vapor Permeance of Weather Resistive Barriers," *Journal of ASTM International*, Vol 2, #10 (West Conshohocken, PA: Nov/Dec 2005)
- Local Government Takes Aim at Invasive Exotic Plants," *Noxious Times*, March 1999
- "Concrete Floor Flatness & Levelness Tolerances," *The Construction Specifier*, November 1994
- "Moisture Problems in Slabs on Grade: An Update," *The*

Construction Specifier, December 1993
- "Thin Brick Veneer," *The Construction Specifier,* August 1993
- "The Condo Conundrum," *The Construction Specifier*, May 1993
- "Be Prepared for Building Failures and Disasters," *Black's Office Leasing Guide*, Winter 1993
- "Avoiding and Repairing Moisture Problems in Slabs on Grade," *The Construction Specifier*, December 1992
- "Common Interest Development Maintenance Manual," *ECHO: Executive Council of Home Owners,* May 1991
- "Building Failure: Limiting the Losses," *Best's Review,* September 1990
- "Thin Brick Veneer: A Guide to Trouble-Free Application," *Sun Coast,* December 1989
- "How CADD Helped Restorations-Documentation and Design For A California Town," *Architecture Magazine,* November 1989
- "Do You Need A Building Detective?," *Facility Manager,* Winter 1988-89
- "Condominium Maintenance Manual," *Community Associations Institute Newsletter,* Vol. 8/No. 2, June/July 1988
- "Arbitrator Discusses Complex Problems of Condo Ownership," *Contra Costa Times,* November 4, 1984
- "Construction Defects in Residential Condominiums," *Courier* (Newsletter of the Council of Condominium Homeowner Associations, Inc.), Vol. 2, Nov./Dec. 1984
- *California Sunshine, A Consumer Guide to Solar Energy,* California Energy Resources and Development Commission (Thomas K. Butt, Project Director), 1977
- *Guidelines for Evaluating New Development in Contra Costa County, CA,* 1976
- *The Working Woodburner, Home Heating and Cooking with Fireplaces and Wood Stoves,* Dennis Dahlin, Author & Thomas K. Butt, Project Manager, 1976
- "Solar Energy Homes, New Market For Realtors," *California Real Estate,* October 1975

REPRESENTATIVE SPEAKING ENGAGEMENTS
- Sheet Metal Flashings, RCI Symposium, Downey, CA, 2011
- Sheet Metal Flashings, WESTCON Symposium, Albany, CA, 2010
- Stucco as a Weather Protection System," a Westcon/RCI seminar, San Diego, 2010
- "Green Buildings and Energy Efficiency," Green is Gold Expo, Richmond, 2009
- "Plaza and Deck Waterproofing," a Westcon/RCI seminar, Long Beach, 2008
- "Stucco as a Weather Protection System," a Westcon/RCI seminar, 2007
- "Water Intrusion – An Age Old Challenge to Architects," Water Intrusion – A Beutler Educational Forum
- Roofing Consultant's Institute, Southern California, ASTM E2266 Symposium on Design and Construction of Low-Rise Frame Building Wall Systems to Resist Water Intrusion
- " The Enduring Mystery of Weather Resistive Barriers and the Need for Standards," Westcon ASTM E2266 Symposium on Design and Construction of Low-Rise Frame Building Wall Systems to Resist Water Intrusion
- "Water Resistance and Vapor Permeance of Weather Resistive Barriers," ASTM Symposium on Performance and Durability of Window-Wall Interface, 2004
- "Specifications and the Need for Standards," BETEC 2004 Symposium on Enclosure Wall Systems
- "Weather Resistive Barriers and Flexible Flashings," Western Region AAMA Meeting, 2004
- "What Elected Officials, Architects, Planners and Local Officials are Doing," Local Government Commission 3rd Annual New partners for Smart Growth Conference, 2004
- "The Design Professional's Standard of Care - Using Reasonable Diligence and Best Judgment," Westcon 2000 Symposium and May, 2001 Meeting
- "Something Fishy is in the Neighborhood," Local Government Commission Building Livable Communities Conference 2000
- "Moisture Problems in Concrete Slabs on Grade," World of Concrete, 1998
- "Forensic and Diagnostic Architecture," AIA Redwood Empire Chapter, 1997
- Moderator and speaker at "Putting Our Communities Back On Their Feet" conference by Local Government Commission, 1996
- "Moisture Problems in Concrete Slabs on Grade," Construction Consultants Association of Northern California, 1996
- "Jobsite Problems, Solutions and Perceptions: Why are the Architect and Contractor Treated So Differently?," The Northern California Construction Institute, 1993
- "Building Failures and Subsidence," California Building Industry Association, Sacramento, CA, 1991
- "Forming and Running a Practice," East Bay Chapter, AIA, Practice Management Seminar Series, 1989, 1990
- Training and Evaluation Seminar, The American Arbitration

Association, Continuing Education for Arbitrators, 1989

- Light House Preservation Workshop, National Trust for Historic Preservation, Annual Convention, 1989
- "Polymer Modifier and Grouts and Mortar," Ceramic Tile
- Institute, Dallas, TX, 1989

MILITARY SERVICE

U.S. Army Corps of Engineers, 1968-1970

Rank at Discharge: 1st Lieutenant

Vietnam Service: 1969-1970

Decorations:

The Bronze Star, Army Commendation Medal, Republic of Vietnam Campaign Medal and Vietnam Service Medal